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S.S. 192.] [O.B. 1432A.
40/W.O./5678.

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THE EMPLOYMENT OF MACHINE GUNS.

PART II.

ORGANIZATION AND DIRECTION OF FIRE.

(ISSUED BY THE GENERAL STAFF.)

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CHAPTER I.

CHAPTER II.

Map Work.

CHAPTER III.

Fire Direction.

NOTE.—The paragraphs marked in the text with an asterisk may be omitted on a first reading.

APPENDICES.

PART I. deals with "The Tactical Employment of Machine Guns."

INDEX.

A.

B.

C.

NOTE.—The terms "Machine Gun," "Barrage," and "Battery" are used throughout this publication in the following senses:—

Machine Gun, to denote the ·303 Vickers Machine Gun.

Barrage fire by Machine Guns is the fire of a large number of guns acting under a centralized control directed on to definite lines or areas in which the frontage engaged by a gun approximates 40 yards. (*See* Sec. 17, para. 1.)

Battery:—A battery of machine guns only exists as a tactical unit in the motor machine gun branch of the Machine Gun Corps. In the Cavalry and Infantry branches the word is merely used as being the most convenient term for denoting a suitable number of guns placed under an officer as a fire unit for a particular purpose. (*See* Part I., Sec. 5.)

PART II.—ORGANIZATION AND DIRECTION OF FIRE.

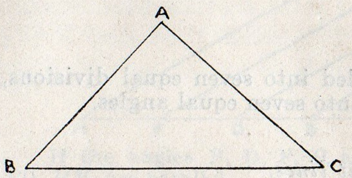
CHAPTER I.

1.—MACHINE GUNNERS' MATHEMATICS.

A knowledge of the following simple mathematical facts is of great assistance in modern machine gunnery.

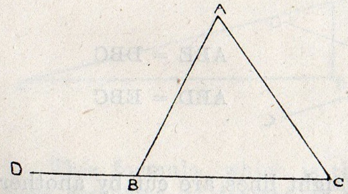
1. *Triangles.*

(i.) The three angles of a triangle are together equal to two right angles. Thus, if any two angles are known, the remaining angle can be found.



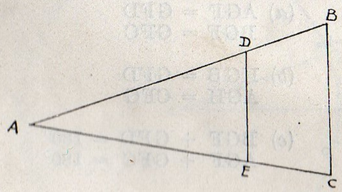
ABC + BCA + CAB = 2 right angles = 180°

(ii.) The exterior angle of a triangle is equal to the two interior and opposite angles.



DBA = BAC + BCA

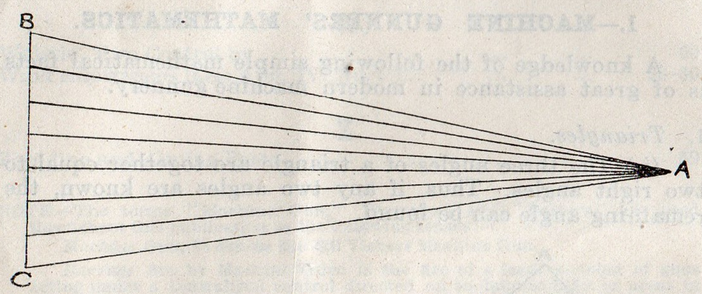
(iii.) If a line is drawn parallel to one side of a triangle, it divides the other side into proportional parts.



DE is parallel to BC

Then $\frac{AE}{AC} = \frac{AD}{AB} = \frac{DE}{BC}$

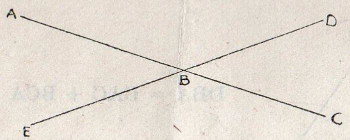
(iv.) *When the apex angle of a triangle is small,* the following is true for all practical purposes:—" If the base of a triangle be divided into a number of equal divisions and these divisions be joined to the apex, then the apex angle will be divided into the same number of equal angles."



Example:—If BC be divided into seven equal divisions, the angle BAC is also divided into seven equal angles.

2. *Angles and parallel straight lines.*

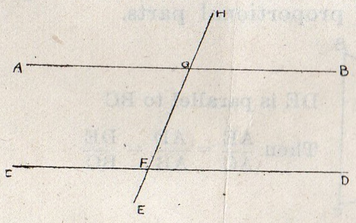
(i.) When two straight lines intersect, the vertically opposite angles are equal.



ABE = DBC

ABD = EBC

(ii.) When two parallel straight lines are cut by another straight line, the following are true:—

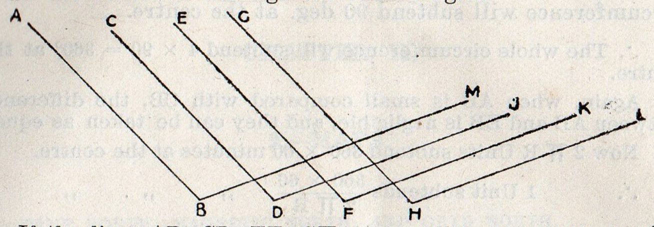


(*a*) AGF = GFD
BGF = GFC

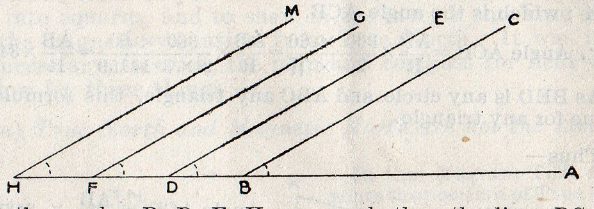
(*b*) HGB = GFD
AGH = CFG

(*c*) BGF + GFD = 180°
AGF + GFC = 180°

(iii.) If straight lines are parallel, they will still be parallel if all are switched through the same angle.

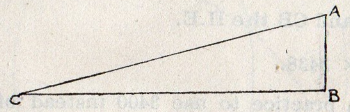


If the lines AB, CD, EF, GH are parallel, then if the angles B, D, F, H are equal, the lines BM, DJ, FK and HL will be parallel.



If the angles B, D, F, H are equal, then the lines BC, DE, FG, HM, are parallel.

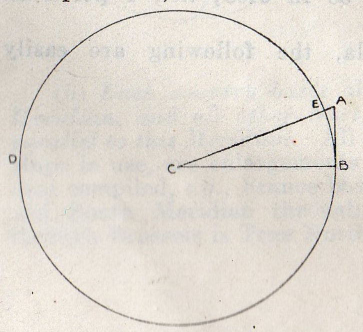
*3. *The " V.I. over H.E." Formula.*



Let AB = V.I. (Vertical Interval).
Let BC = H.E. (Horizontal Equivalent).
Let angle ABC = 90°
Then provided AB is small in comparison with BC, the angle ACB (in minutes)

$$= \frac{\text{V.I.}}{\text{H.E.}} \times 3400.$$

This formula, which is the basis of almost all Machine Gun problems, is derived as follows:—



If the circumference of any circle be divided by the diameter, the same result is always obtained; the circumference being 3·14159 times the diameter.

This figure 3·14159 is always denoted by π.

$\therefore$ Circumference $= \pi \times$ diameter.

$= \pi \times 2$ R

where R is the radius.

Also the curved line BE is said to "subtend" the angle ECB at the centre. It is clear that a quarter of the circumference will subtend 90 deg. at the centre.

$\therefore$ The whole circumference will subtend $4 \times 90 = 360°$ at the centre.

Again, when AB is small compared with CB, the difference between AB and EB is negligible, and they can be taken as equal.

Now $2 \pi R$ Units subtend 360×60 minutes at the centre.

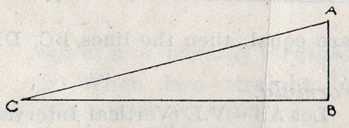
$\therefore$ 1 Unit subtends $\dfrac{360 \times 60}{2 \pi R}$,, ,, ,,

$\therefore$ AB (*i.e.* BE) units subtend $\dfrac{360 \times 60 \times AB}{2 \pi R}$ minutes at the centre; which is the angle ACB.

$$\therefore \text{ Angle ACB} = \frac{AB}{R} \times \frac{360 \times 60}{2 \times \pi} = \frac{AB}{R} \times \frac{360 \times 60}{2 \times 3{\cdot}14159} = \frac{AB}{R} \times 3438.$$

As BED is any circle and ABC any triangle, this formula will be true for any triangle.

Thus—



$$\text{Angle ACB} = \frac{AB}{CB} \times 3438$$

(in minutes).

Now AB represents the V.I., and CB the H.E.

$$\therefore \text{ Angle in minutes} = \frac{\text{V.I.}}{\text{H.E.}} \times 3438.$$

It will be more convenient in practice to use 3400 instead of 3438 and thus we get:—

$$\text{Angle in minutes} = \frac{\text{V.I.}}{\text{H.E.}} \times 3400.$$

The error introduced is 38 in 3438; *i.e.*, 1 per cent. approximately.

From the above formula, the following are easily obtained:—

$$\text{V.I.} = \frac{\text{Angle} \times \text{H.E.}}{3400}$$

$$\text{H.E.} = \frac{\text{V.I.} \times 3400}{\text{Angle}}$$

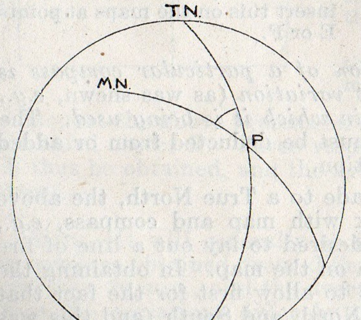
CHAPTER II.

2.—MAPS.

1.—TRUE NORTH, MAGNETIC NORTH, AND GRID NORTH.

On the older maps it was usual to divide the map by grid lines into squares, and to shew in the margin the True North and the magnetic variation from True North. It was therefore necessary, in using the map and compass for field work, to allow for three things:—

(*a*) *True North and Magnetic North are not the same.*

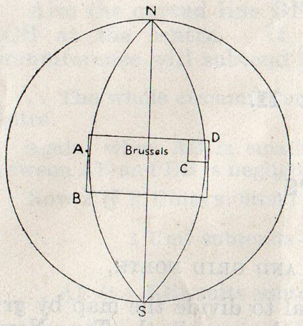


In this diagram T.N. represents the position of True North (at the North Pole), and M.N. represents the position of Magnetic North (a point at present in the northern extremity of North America).

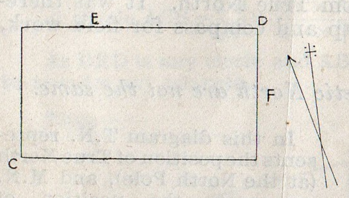
If any point P is taken on the Globe, True North will be in the direction of T.N. and Magnetic North will be in the direction of M.N.

The angle TPM is the magnetic variation for the point P, and not only does this angle vary for different points, but it also varies year by year for any particular point.

(*b*) *Each country bases all its maps on one particular Meridian, and all other North and South lines are drawn parallel to this Meridian.* All other maps, such as the Trench Maps in use, are enlargements of portions of an original map thus compiled, *e.g.*, France bases its maps on the True North and South Meridian through Brussels, and the grid line through Brussels is True North and South.



But if any other point A is taken, the line AB, though parallel to NS, is not True North and South. The curved line SAN is True North and South.



When a small part of this map is enlarged (*e.g.* CD) there is no grid line on the map which is True North and South. The deviation of the grid line from True North must therefore be allowed for, and it was usual to insert this on the maps at points E or F.

(*c*) *The magnetic variation of a particular compass is rarely the same as the correct variation* (as was shewn, *e.g.*, on the map) *for the locality in which it is being used.* The compass has an error which must be deducted from or added to the correct magnetic variation.

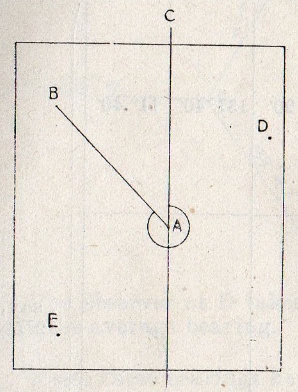
So long as reference is made to a True North, the above three things complicate work with map and compass, *e.g.*, suppose the machine gunner desired to lay out a line of fire by compass to a target shewn on the map. In obtaining the bearing from the map he had to allow first for the fact that the grid lines were not True North and South (and this was often difficult because the difference was not clearly shewn); and secondly for the error of his particular compass. Finally he had to remember whether the magnetic variation had to be added or subtracted. It is therefore better, as is now done on maps, to omit True North altogether, and work simply by Compass North and Grid North as follows:—

(i.) Find the magnetic variation of your compass from the grid lines on map.

(ii.) Measure all bearings with reference to the grid lines on the map.

(iii.) To convert a grid bearing into a compass bearing, add (in France) the magnetic variation of your compass: and conversely to convert a compass bearing into a grid bearing, subtract (in France) this variation.

To find the magnetic variation of a compass from the grid lines on the map.



Select two distant points A an B, which are mutually visible o the ground and which are accurately marked on the map.

With the compass, take three separate bearings from A to B.

Take the mean of these three bearings as being the correct magnetic bearing of the compass from A to B (Say 324° 40′).

On the map, measure the bearing of AB with reference to the Grid North and South line passing through A (*i.e.*, AC). (Say 312° 20′).

Then the magnetic variation of that particular compass from this map, is 324° 40′ − 312° 20′ = 12° 20′.

Repeat the above process on a second object D, and again on a third object E. Three values for the compass variation will thus be obtained, and the average value may be taken as correct.

Note.—It will generally be found that the variations of the compass obtained from different points do not differ by more than 30 min., and the average value may be taken; but where the variations differ by more than 1 deg. it will be necessary to note the variation in each direction. This difference is due to the compass cards being incorrectly centred. Where the error is considerable it is best to procure a new compass.

The above results can be conveniently arranged as follows:—

	Map Location from which bearings are taken	Map Location on which bearings are taken	Magnetic bearing	Mean Magnetic bearing	Grid bearing	Variation	Average Compass Variation
1.	R.21.d. 42·60	R.28.c. 10·14	(i.) 143° 10′ (ii.) 143° 30′ (iii.) 143° 20′	143° 20′	131° 40′	11° 40′	
2.							, say, 12° 5′
3.							

The compass variation must be found for every new map and in every fresh locality.

2. RESECTION.

The position on the ground being known, to find it on the map.

Accuracy is essential at every stage.

(i.) Find out your exact compass variation.

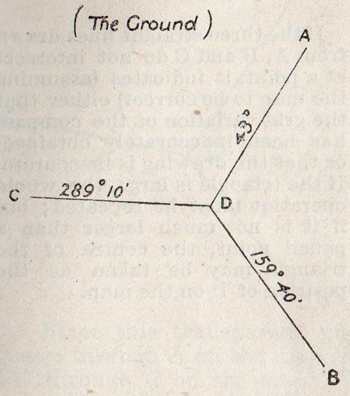
(ii.) Take several accurate bearings and take the mean as correct.

(iii.) Avoid metal likely to affect the compass readings.

(iv.) Draw carefully with a hard sharp pencil.

(v.) Whenever possible fix the position on the map by the detail close at hand rather than by resection.

Method A. Using compass.



The observer at D, wishing to fix the position of D on t e map, selects two points A and B, visible on the ground and accurately marked on the map, and whenever possible a third point C, which checks the position of D, as fixed by AD and BD.

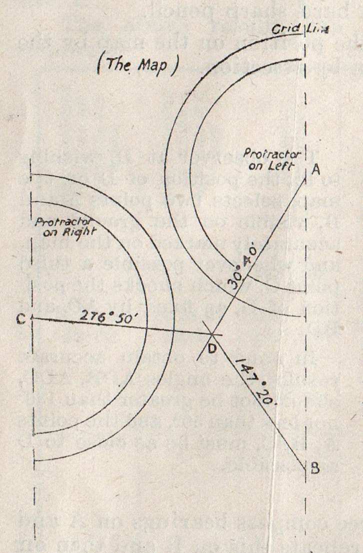
In order to obtain accurate results, the angles ADB, ADC, should not be greater than 130° nor less than 50°, and the points A, B, C, must be as close to D as possible.

The observer at D takes three compass bearings on A and finds the average bearing. He repeats this on B and then on C.

From these bearings he obtains the grid bearings to A, B and C, by subtracting his compass variations from each.

Obje taken	Average Compass Bearing	Grid Bearing	
A.	43°	30° 40′	When the grid variation of the compass is 12° 20′.
B.	159° 40′	147° 20′	
C.	289° 10′	276° 50′	

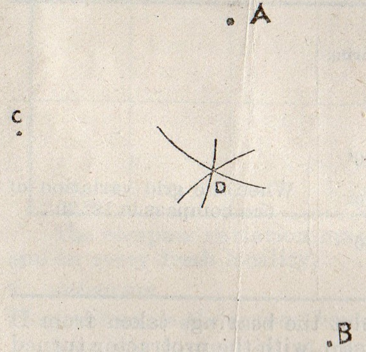
To plot these resections, plot the bearings taken from D at the points identified on the map, with the protractor turned to the right for bearings over 180 deg. and turned to the left for bearings under 180 deg. This is quite simple with a protractor graduated in both directions.



If the three straight lines drawn from A, B and C do not intersect at a point, it indicates (assuming the map to be correct) either that the grid variation of the compass has been inaccurately obtained, or that the drawing is inaccurate. If the triangle is large, the whole operation must be repeated; but if it is not much larger than a pencil point, the centre of the triangle may be taken as the position of D on the map.

Method B. Using a range-finding instrument.

This method is very useful when it is impossible to use a compass. The instrument must be accurately adjusted.



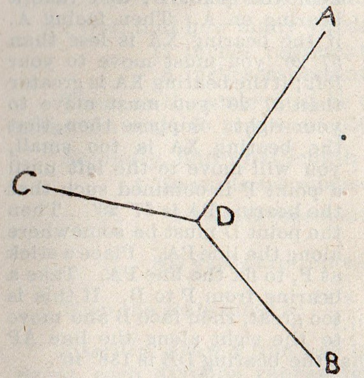
From D, the point whose position on the map is desired, take the range to three points A, B and C. These should be as near as is consistent with the minimum reading of the instrument (250 yards on the Barr and Stroud).

Then with a pair of compasses stretch the distance AD by the scale on the map, and with compass point at A, draw an arc. Repeat this for B and C, and the point of intersection of the three arcs will be the position of D.

In this case also, a triangle at D and not a point, indicates inaccuracy, and the same rule applies as in Method A.

Method C. Method of super-position.

Using a machine gun with direction dial, or a compass.



From D find the angles ADB, BDC and CDA by laying on A, B, C, in succession and reading off the angles on the direction dial.

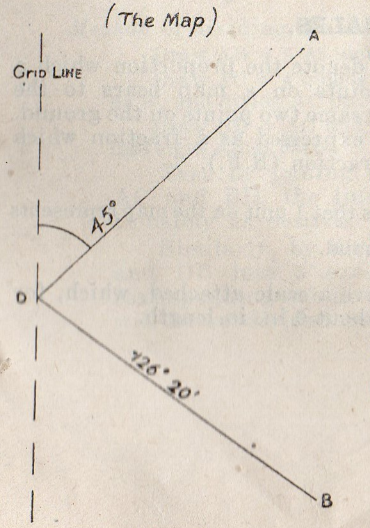
Then on a piece of transparent paper draw a line AD, and from D draw a line DB so that the angle ADB = the angle ADB found above. Similarly draw DC making the angle CDB = the angle CDB found above.

Place this transparent paper on the map, so that DA passes through A on the map, DB through B on the map, and DC through C on the map. With a pin, prick through the point D, and the point thus obtained will be the position of D on the map.

NOTE.—The best results will be obtained when the points A, B, C are near D.

Instead of the Direction Dial the compass may be used. Take bearings on A, B and C. By subtracting the bearing of A from that of B obtain the angle ADB, and by subtracting the bearing of B from that of C obtain the angle BDC.

The position on the map being known, to find it on the ground.



Select two points A and B which are recognisable on the ground and are marked on the map.

On the map join A and B, to D.

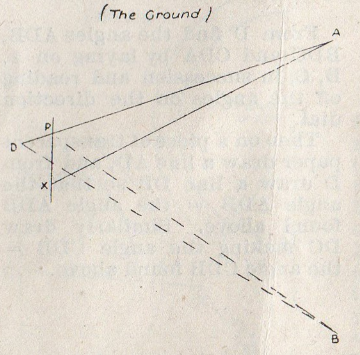
Through D draw a line parallel to the grid lines of the map, and by laying the centre of the protractor on D find the grid bearings from D to A, and B. Convert these bearings to compass bearings, by adding the compass variation.

Then with a compass variation of 12° 20′

From D the compass bearing to A = 45° + 12° 20′ = 57° 20′

From D the compass bearing to B = 126° 20′ + 12° 20′ = 138° 40′.

Proceed next on the ground to a point X, which you imagine is



near the point D, and take a bearing on A. Then facing A, if the bearing XA is less than 57° 20′ you must move to your left; if the bearing XA is greater than 57° 20′ you must move to your right. Suppose then, that the bearing XA is too small, you will move to the left until a point P is obtained such that the bearing PA is 57° 20′. Then the point D must be somewhere along the line PA. Place a stick at P, to fix the line PA. Take a bearing from P to B. If this is too great, then face B and move to the right along the line AP until a point D is obtained such that the bearing DB is 138° 40′.

Then D is the point required, because the bearing DA is 57 deg. 20 min., and the bearing DB is 138 deg. 40 min., which was required.

NOTE.—(i.) As a final check, the bearing on a third point should be obtained.

(ii.) Whenever possible, fix the position D by detail close at hand.

When the obliteration of all landmarks makes resection impossible, it is sometimes possible to get the position fixed by the help of the Field Artillery or a Field Survey Company.

3.—SCALES.

The word scale is used to denote the proportion which a distance between any two points on a map bears to the horizontal distance between the same two points on the ground. This same proportion can be expressed as a fraction which is called the Representative Fraction (R.F.).

Thus R.F. $= \frac{1}{20{,}000}$ indicates that 1 unit on the map represents 20,000 of the same unit on the ground.

A sketch should always have a scale attached, which, for convenience of use, should be about 6 in. in length.

To construct a scale of 12 inches to the mile, showing divisions of 100 yards and sub-divisions of 20 yards:—

First, find how many yards are represented by 6 inches.

12 inches represents 1,760 yards.

∴ 6 inches represents 880 yards.

Then, as the scale must be divided into hundreds of yards, make the scale to represent 800 yards.

Secondly, find what length of line will represent 800 yards.

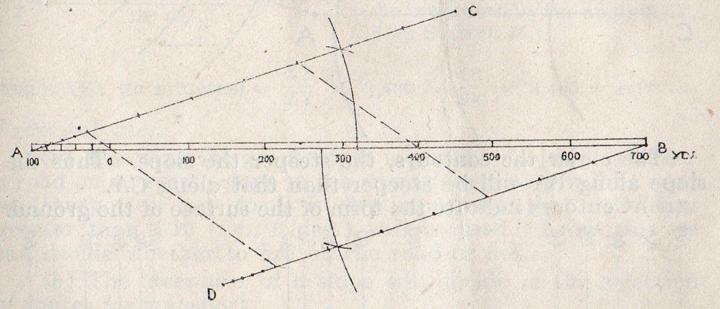
1,760 yards are represented by 12 inches.

∴ 1 yard is represented by $\frac{12}{1{,}760}$ inches.

∴ 800 yards are represented by $\frac{12}{1{,}760} \times \frac{800}{1}$ inches.

Then the scale must be $\frac{12 \times 800}{1{,}760} = 5{\cdot}45$ inches.

Thirdly, draw a line 5·45 inches, and divide it into 8 equal parts, each division representing 100 yards. Divide the left division into 5 equal parts, each representing 20 yards.



Method of dividing the scale into parts:—

Draw AB = 5·45 inches.

Draw AC = 4 inches (this length being easily divisible by 8), and divide AC into eight equal parts.

Draw BD = AC and parallel to AC and divide it also into eight equal parts.

Then by joining the corresponding divisions of AC and BD, the line AB will be divided proportionately as desired.

Similarly, by dividing the left divisions of AC and DB into 5 equal parts and joining up the corresponding sub-divisions, the left division of AB will be subdivided as desired.

4.—CONTOURS.

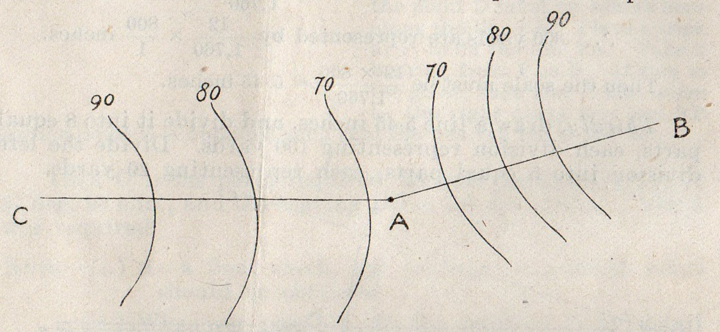
1. DEFINITION.

"The representation of an imaginary line running along the surface of the ground, at the same height above mean sea-level throughout its length."

Only a certain number of these lines are drawn on the map, and the heights of intermediate points must be estimated. Generally on our maps of 1/10,000 and 1/20,000, contours shew each vertical distance of 10 metres, which is called the Vertical Interval between the contours.

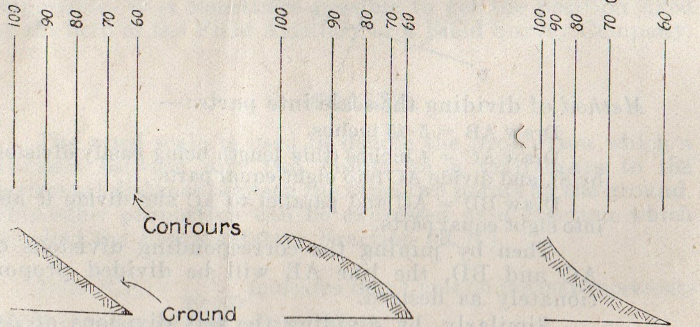
2. EXAMINATION OF A MAP.

(i.) Contours indicate the relative steepness of slopes.



The closer the contours, the steeper the slope. Thus the slope along BA will be steeper than that along CA.

(ii.) Contours indicate the form of the surface of the ground.

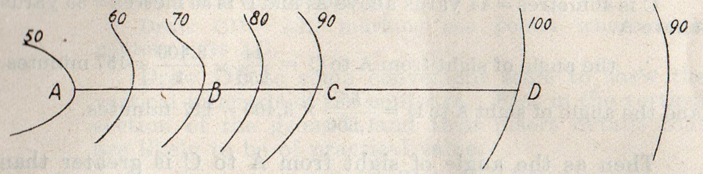


I. Contours equidistant. Slope uniform.

II. Contours becoming closer, going from high to low ground. Surface is convex and there will be dead ground.

III. Contours becoming wider, going from high to low ground. Surface concave, and there will not be dead ground.

(iii.) From contours the gradient, or steepness of slope, can be calculated.

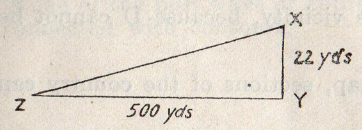


(AB = 500 yards).

Example:—The slope A to B is required.

Suppose AB = 500 yards. (= ZY).

B is 20 metres = 22 yards above A. (= XY).



Then the gradient is "22 in 500," or written as a fraction $= \frac{22}{500} = \frac{1}{22 \cdot 7}$ The steepness of the slope can also be measured by the angle XZY. (*See* Section 45.)

$$\text{Angle XZY (in minutes)} = \frac{XY}{ZY} \times 3{,}400 = \frac{22}{500} \times 3{,}400 = 149'$$

Practical uses.

(*a*) Knowing the gradient, it is possible to judge whether a road on a reverse slope in the enemy's territory will be used by transport or not; for it is very improbable that a gradient greater than 1-10 (*i.e.*, 6 deg.) will be used. From this we can decide whether to fire on the road or not.

(*b*) The steepness of a slope will decide in the selection of routes for transport.

If the gradient is 1-20 (*i.e.*, 3 deg.), even on a good road, time must be allowed to breathe the horses.

On a gradient of 1-10 (*i.e.*, 6 deg.), a horse can only draw one quarter of the load it can draw on the level.

(*c*) Knowing the slope of the ground fired on, several deductions can be made of probable fire effect. (*See* "Fire effect in relation to slope of ground." Sec. 49, para. 2.)

(iv.) From contours, one can find whether two points are mutually visible.

Example:—*See* Diagram in (iii.).

Is the point D visible from the point A? C is the point likely to cause the obstruction.

Now AC = 950 yards, and AD = 1,600 yards.

C is 40metres = 44 yards above A, and D is 50 metres = 55 yards above A.

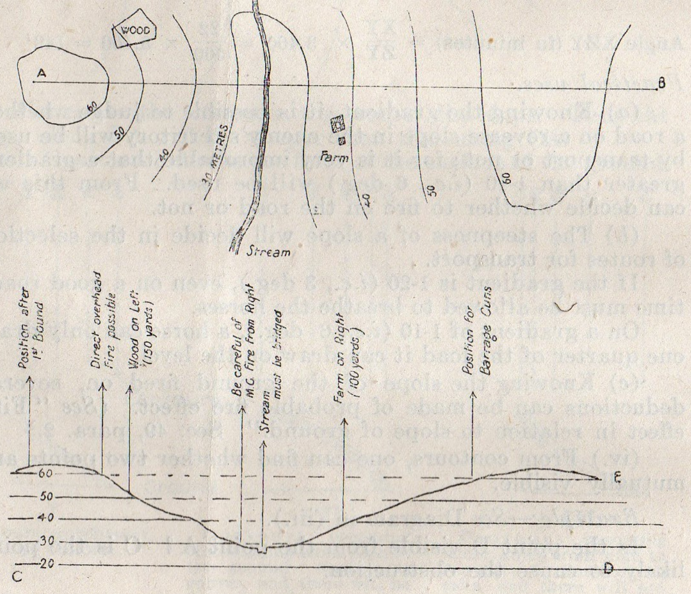
$\therefore$ the angle of sight from A to C $= \frac{44}{950} \times \frac{3,400}{1} = 157$ minutes,

and the angle of sight A to D $= \frac{55}{1,600} \times 3,400 = 117$ minutes.

Then as the angle of sight from A to C is greater than that from A to D, the point D is not visible from A.

The practical use of the above would be in selecting routes of advance either for troops or for transport. For instance in the previous diagram, suppose we hold C and the enemy holds A, it would be safe for troops to cross D, although D is the highest point in the vicinity, because D cannot be seen from A.

(v.) From a contoured map, sections of the country can be made.



In the above contours, to make a section from A to B:—

Join AB on the map.

Draw CD = AB, marking the points where each contour cuts AB.

Draw DE to some convenient scale to shew the vertical intervals of the contours. Plot in the vertical section of the ground: and then insert details that are likely to be of practical value.

A section thus constructed will be useful, for example, for shewing troops the kind of ground over which they have to advance, especially if aeroplane photographs are difficult to obtain.

For purposes of study, the construction of such sections is one of the best ways of appreciating the different problems connected with contours.

CHAPTER III.

FIRE DIRECTION.

5.—THEORY OF FIRE.

1. TECHNICAL TERMS.

Axis of the bore.—An imaginary line following the centre of the bore from breech to muzzle.

Line of sight.—The straight line passing through the sights and the point aimed at.

Trajectory.—The curved path taken by the bullet in its flight to the target.

Cone of fire.—The figure formed in the air by the trajectories of the outermost shots of a burst of fire.

Culminating point.—The highest point of the trajectory above the line of sight.

Its position is approximately 6-10 of the range.

First catch.—The point where the lowest bullet has descended sufficiently to strike the head of a man, whether mounted, standing, kneeling, lying, etc.

First graze.—The point where the lowest bullet, if not interfered with, will first strike the ground.

Beaten zone.—The area of ground beaten by a cone of fire.

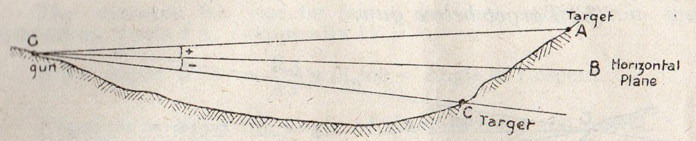
(i.) The length is great compared with the width.

(ii.) The dimensions of the beaten zones of the Vickers gun have never been satisfactorily measured, and recent experiments with average guns and average firers indicate that the beaten zones are longer and narrower than the official dimensions in Appendix IV., Table I.

Effective beaten zone.—The area of ground beaten by the best 75 per cent. of the shots.

Drift.—The term used to express the lateral deviation of the bullet, brought about by its gyroscopic action, after it has left the barrel. Experience indicates that for purposes of machine gun fire drift need not be taken into consideration.

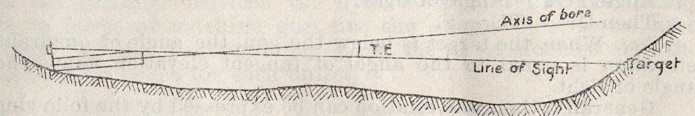
Angle of sight.—The angle contained between the line of sight and the horizontal plane.



Angle AGB = angle of sight for target A.
Angle BGC = „ „ „ „ „ C.

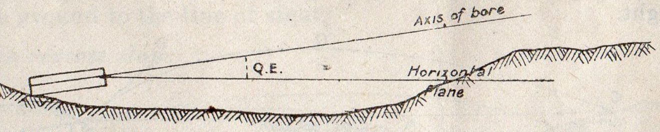
By convention, the angle is said to be positive (+) when the target is above the H.P., and is negative (−) when the target is below the H.P., through the gun position.

Angle of tangent elevation.—The angle between the axis of the bore and the line of sight.



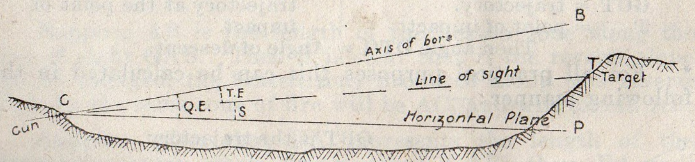
T.E. is the angle of tangent elevation.

Angle of quadrant elevation.—The angle between the axis of the bore and the horizontal plane.



Relation between angles of quadrant elevation (Q.E.), angle of tangent elevation (T.E.), and angle of sight.

(a) Target above gun.

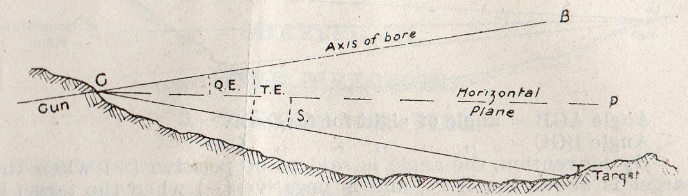


By definition:—

Angle BGP = Angle of quadrant elevation.
Angle BGT = Angle of tangent elevation.
Angle TGP = Angle of sight.
Then QE = TE + S.

i.e., When the target is above the gun, the angle of quadrant elevation is equal to the angle of tangent elevation, plus the angle of sight.

(*b*) *Target below gun.*



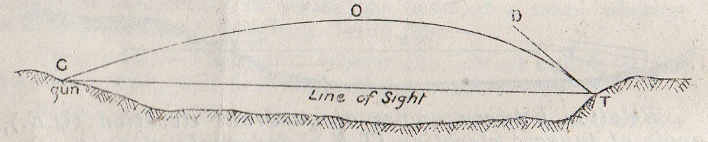
By definition :—

Angle BGP = Angle of quadrant elevation.
Angle BGT = Angle of tangent elevation.
Angle PGT = Angle of sight.
Then QE = TE − S.

i.e., When the target is below the gun, the angle of quadrant elevation is equal to the angle of tangent elevation minus the angle of sight.

Generally, then, the relation can be expressed by the following formula :—$QE = TE \pm S$.

Angle of descent.—The angle which the tangent to the trajectory, at the point of impact, makes with the line of sight.

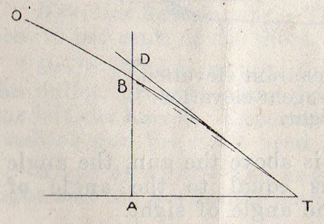


GT = line of sight.
GOT = trajectory.
T = point of impact.

DT is the tangent to the trajectory at the point of impact.

Then angle DTG = Angle of descent.

* For all practical purposes this can be calculated in the following manner :—



OBT is the trajectory.

AT = line of sight.

DT = tangent at point of impact.

Then if AT = 100 yards, the trajectory BT will be practically coincident with the tangent DT, and we can assume that the angle BTA = DTA.

The distance BA can be found for any range, from the Trajectory Table 2 A. (Appendix IV.)

$$\text{Then angle BTA} = \frac{BA}{AT} \times 3{,}400 = \text{Angle of Descent.}$$

Example:—Find the angle of descent for 1,800 yards.

From Table 2 A find the height BA, *i.e.*, the height of the 1,800 yards trajectory at 1,700 yards. This equals 12 yards.

$$\text{Then angle of descent} = \frac{BA}{AT} \times 3{,}400\ \frac{12}{100} \times 3{,}400 = 408 \text{ min.}$$

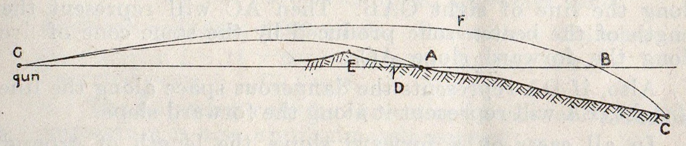
(Compare Table I., Column 3).

Dangerous space.—For one bullet, the dangerous space is the distance between the first catch and the first graze. In a burst of machine gun fire the *danger zone* is an area equal to the beaten zone, *plus* the area formed by the dangerous space for each bullet.

2. FIRE EFFECT IN RELATION TO SLOPE OF GROUND.

On level ground the length of the beaten zone varies considerably with the range; but also at any particular range the length of the beaten zone varies with the inclination of the ground to the line of sight.

The reverse slope.



Suppose AB is the length of the beaten zone along the line of sight GAB. Then it is clear that if the reverse slope AC be engaged, the beaten zone produced along this reverse slope by the same cone of fire will be AC, and will exceed AB.

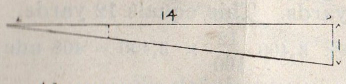
Suppose, also, that DA represents the length of the dangerous space when firing along GAB, then EA will represent the length of the dangerous space when firing on the reverse slope.

Along the line of sight, therefore, fire effect will be produced for a distance DB, but on a reverse slope fire effect will be produced for a distance EC, and this distance (as will be shown later) will greatly exceed DB.

On a reverse slope the ratio of the length of AC to that of AB at any range can be found as follows:—

$$\frac{AC}{AB} = \frac{\text{Angle of descent}}{\text{Angle of descent} - \text{Angle of slope of ground}} = \frac{FBA}{FBA - BAC}$$

Example:—Range 2,000 yards. Slope of ground 1 in 14.



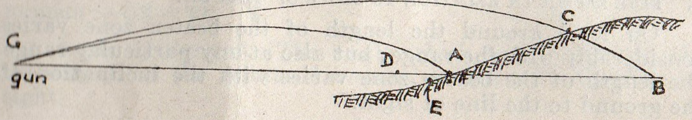
NOTE.—If the ground slopes 1 in 14, the angle of slope $= \frac{1}{14} \times 3{,}400 = 251'$.

Also angle of descent at 2,000 yards = 541′.

$$\frac{AC}{AB} = \frac{541}{541 - 251} = \frac{541}{290} = 1 \cdot 8.$$

Therefore AC is 1·8 times (*i.e.*, nearly twice) the length of AB at 2,000 yards when the ground slopes 1 in 14.

The forward slope.



Again let AB represent the length of the beaten zone along the line of sight GAB. Then AC will represent the length of the beaten zone produced by the same cone of fire along the forward slope AC.

Also, if DA represents the dangerous space along the line of sight, EA will represent it along the forward slope.

In all cases on a forward slope, the length of ground effectively engaged (*i.e.*, EC) will be less than on the line of sight (*i.e.*, DB).

On a forward slope, the ratio of the length of AC to that of AB is found as follows:—

$$\frac{AC}{AB} = \frac{\text{Angle of descent}}{\text{Angle of descent} + \text{Angle of slope of ground}} = \frac{CBA}{CBA + CAB}$$

Example:—Range 1,500. Slope of ground 1 in 12 (*i.e.*, angle of slope = 298′).

$$\frac{AC}{AB} = \frac{251}{251 + 298} = \frac{251}{549} = \frac{5}{11}$$

Thus AC will be less than half the length of AB, at 1,500 yards when the ground slopes 1 in 12.

3. CLIMATIC INFLUENCES AND THEIR ALLOWANCES.

The following are the normal atmospheric conditions for the Sighting of Small Arms:—

(i.) Barometric pressure. 30 inches. (Sea level.)
(ii.) Temperature. 60 deg. Fahrenheit.
(iii.) Still air.
(iv.) A horizontal line of sight.

(*A*) *Atmospheric variations that affect elevation.*

When the barometer rises above 30 inches, more elevation than is normally required for the distance will be necessary, owing to the greater resistance offered to the bullet by the denser atmosphere. If the barometer falls below 30 inches, as is the case in damp weather, or at a height above sea level, less elevation will be required, as the atmosphere will offer reduced resistance to the bullet. In the same manner the bullet meets with less resistance in hot weather when the thermometer is high, and greater resistance in cold weather when it is low.

(i.) The following rule for correction in case of variation in barometric pressure is approximately correct:—

For every inch the barometer rises or falls above or below 30 inches, add or deduct $1\frac{1}{2}$ yards for each 100 yards of range.

When the barometer rises, add—*vice versâ*.

Example:—Range, 2,000 yards. Barometer, 29 inches.

Allowance $= 1 \times 1\frac{1}{2} \times 20 = 30$ yards. (Deduct this.)
Corrected range = 1,970 yards.

(ii.) The following rule for correction in case of variation in temperature is also approximately correct:—

For every degree which the temperature rises or falls above or below 60 deg., deduct or add 1-10 yards for each 100 yards of range.

Example:—2,100 yards. Temperature, 50 deg.

$$\text{Allowance} = \frac{1}{10} \times (60 - 50) \times \left(\frac{2{,}100}{100}\right)$$
$$= \frac{1}{10} \times \frac{10}{1} \times \frac{21}{1} = 21 \text{ yards. (Add this.)}$$

Corrected range = 2,121 yards.

(iii.) The following rule for correction in case of head or rear winds is approximately correct:—

$$\text{Allowance in yards} = \frac{\text{Speed of wind in miles per hour} \times \text{Time of flight.}}{2}$$

If an oblique wind, divide the speed by two, and call it head or rear, as the case may be. (*See* also Note (iv.) below.)

Example :—Wind from left front at 20 M.P.H. Range 1,950 yards. This wind is equivalent to a head wind of 10 M.P.H.

Then allowance $= \frac{10 \times 6}{2} = 30$ yards.

Corrected quadrant elevation = 1,980 yards.

Table 4, Appendix IV., has been introduced to save these lengthy calculations, and, with practice, the corrected range for any atmospheric conditions can be worked out in less than half a minute.

(*B*) *Atmospheric variations that affect direction.*

A side wind acts on the greater surface of the bullet, and has consequently more influence on its flight than a wind blowing from the front or rear.

One must also note that, owing to the increased time during which the bullet is exposed to the effect of wind, and to the height attained in its flight, the allowance for wind at long range is out of all proportion to that necessary at short range.

The following table will act as a rough guide:—

Range.	Lateral Allowances. (*cf.* Table 5, App. IV.)					
	Mild. 10 M.P.H.		Fresh. 20 M.P.H.		Strong. 30 M.P.H.	
Yards.	Yards.	Minutes.	Yards.	Minutes.	Yards.	Minutes.
500	1	5	1½	10	2	15
1,000	3	10	6	20	9	30
1,500	6	15	12	30	18	45
2,000	12	20	24	40	36	60
2,500	24	30	48	60	72	90

Notes :—

(i.) Halve the allowances for oblique winds. (*See* Note iv.)

(ii.) For direct fire the minutes of angle should be used in conjunction with a card and string, in order to obtain an

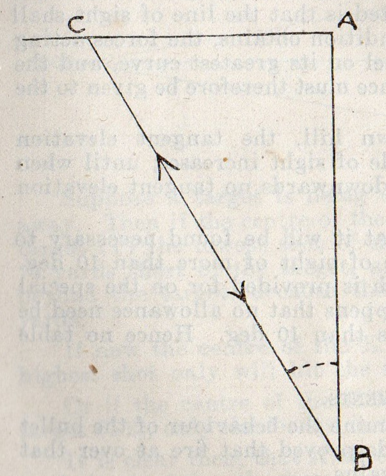
auxiliary aiming mark. If there is no aiming mark available use the following rough rule :—

Assume the following factors :—Mild 2. Fresh 3. Strong 4. Then multiply the range by the appropriate factor, and the first figure of the answer gives the taps required.

Example :—Fresh wind at 1,500 yards : 1,500 × 3 = 4,500 : Order 4 taps.

(iii.) For indirect fire make the allowance in minutes of angle, either by the Deflection Bar Foresight, or with a " T " Aiming Mark placed 9½ yards away, so that one inch lateral distance will represent 10 minutes.

(iv.) The rule that oblique winds should be halved in order to find the equivalent head, rear, or side wind is only very approximately correct, and when greater accuracy is required the following table should be employed to determine what ratio of the wind will act in the direction of the line of fire, *i.e.*, affect the elevation, and what ratio will act at right angles to the line of fire, *i.e.*, affect the direction.



BA gives the line of fire.

The direction of the wind may be CB or BC.

Angle A.B.C.	Ratio of wind affecting elevation.	Ratio of wind affecting direction.
10° } 20°	1	$\frac{1}{4}$
30° } 40°	$\frac{3}{4}$	$\frac{1}{2}$
50° } 60°	$\frac{1}{2}$	$\frac{3}{4}$
70° } 80°	$\frac{1}{4}$	1

Example:—An oblique head wind of 20 miles per hour is blowing at an angle of 30 deg. to the line of fire. Then this is equivalent to a head wind of 20 x $\frac{3}{4}$, *i.e.*, 15 M.P.H., and a side wind of 20 x $\frac{1}{2}$, *i.e.*, 10 M.P.H.

(*C*) *Effect of not having a horizontal line of sight.*

As previously stated, one of the normal conditions under which a machine gun is sighted is that the line of sight shall be horizontal. When this condition obtains, the forces acting on the bullet cause it to travel on its greatest curve, and the elevation for any given distance must therefore be given to the gun.

When firing up or down hill, the tangent elevation required gets less as the angle of sight increases, until when firing vertically upwards or downwards no tangent elevation is required at all.

It is very improbable that it will be found necessary to engage a target at an angle of sight of more than 10 deg. (except hostile aircraft, which is provided for on the special sights issued), and it also happens that no allowance need be made for angles of sight less than 10 deg. Hence no table for correction is necessary.

4. RESULTS OF RECENT EXPERIMENTS.

Experiments made to examine the behaviour of the bullet at ranges of about 3,000 yards proved that fire at over that range will be of very little value.

The shape and size of each beaten zone would appear to vary with each burst fired, and the area beaten is always very large. This is no doubt due to the fact that the bullets attain

a great height, and are influenced by many varying air currents.

The bullet also appears to fall sideways, sometimes pointing to the right and sometimes to the left, indicating that it has ceased to rotate with its point foremost.

The power of penetration was also tested, and the bullet was able to penetrate into $1\frac{1}{2}$ inches of soft wood.

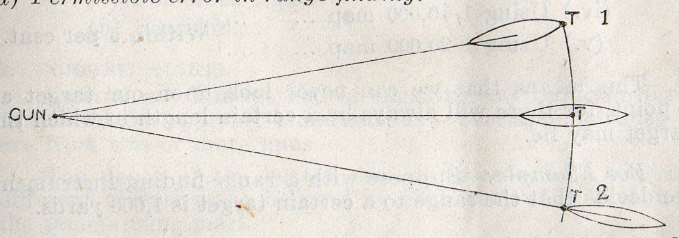
On the other hand, barrage demonstrations at 2,500 and 2,600 yards prove that accurate and effective firing can be produced at these ranges.

Other experiments showed that new barrels shoot higher than old ones, and that after 20,000 rounds the bullets drop short about 5 per cent. of the range.

6.—COMBINED SIGHTS, SEARCHING AND TRAVERSING.

1. PERMISSIBLE AND PROBABLE ERRORS IN RANGE FINDING.

(*a*) *Permissible error in range finding.*



Suppose a target is being engaged which is 1,000 yards away. Then if the centre of the effective beaten zone hits the target (T) the lowest shot of the E.B.Z. will hit the ground 70 yards short of the target, and the highest shot 70 yards beyond the target, because the length of the E.B.Z. is 140 yards.

If now the centre of the E.B.Z. falls 70 yards short, the highest shot only will hit the target (T1).

Or if the centre of the E.B.Z. falls 70 yards beyond the target (T2), only the lowest shots will hit the target.

It is clear then, that if an error of more than 70 yards is made in obtaining the distance to the target (T), the whole of the fire effect will be lost, because the target will not be hit. Seventy yards can be called the permissible error; and it is half the length of the effective beaten zone.

In general, the length of beaten zone decreases, as the range increases, and consequently the permissible error *decreases* as the range increases.

(*b*) *Probable error in range finding.*

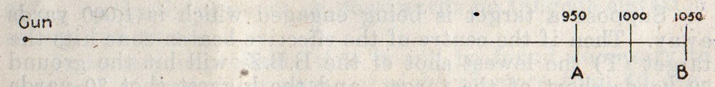
Whether the fire be direct or indirect, the range to any given target can rarely be obtained with complete accuracy, and the magnitude of this probable error depends on the method employed in obtaining the range.

The following table will act as a rough guide:—

(i.)	Using range-finding instrument,	5 per cent. error.
(ii.)	Using a range card built up from key ranges, the key ranges being found by instrument, and the intermediate ranges by judging distance	10 per cent. error.
(iii.)	Judging distance (by eye) ...	15 per cent. error.
(iv.)	Using 1/10,000 map	Within 5 per cent.
(v.)	Using 1/20,000 map	Within 5 per cent.

This means that we can never look upon our target as a point, for there will always be a certain length in which the target may lie.

For Example:—Suppose with a range-finding instrument we decide that the range to a certain target is 1,000 yards.



Then as an error of 5 per cent. may have been made either way, the target may be anywhere between the points A and B; and to ensure hitting the target, we must produce fire effect on the whole of the line AB.

AB in this case is twice the probable error, and $= 2 \times 5$ per cent. of the range.

It is clear that the greater the range, the greater the probable error will be. For example, in this case considered above, the probable error is 50 yards, but if the range had been 2,000 yards, the probable error would have been 100 yards.

To consider the permissible and probable errors together:—

Example:—Range 2,000 yards, using range-finding instrument.

Ground to be searched = 2 × 5% of range = 200 yards.
Permissible error = 35 yards.

Example:—Range 1,500 yards, using key ranges.

Ground to be searched = 2 × 10% of range = 300 yards.
Permissible error = 40 yards.

Example:—Range 1,000 yards, using judging distance method.

Ground to be searched = 2 × 15% of range = 300 yards.
Permissible error = 70 yards.

Therefore, in practically all cases, it is necessary to increase the depth of the beaten zone considerably in order to ensure fire effect.

There are two methods of doing this:—
(*a*) Combined sights.
(*b*) Searching.

2. COMBINED SIGHTS.

Definition:—The method of engaging any required depth of ground by applying simultaneously overlapping zones of fire from two or more guns.

The depth of the beaten zone is increased by ordering different elevations to be used by each gun, while each uses the same aiming mark.

In direct fire these different elevations are put on by ordering each gun to fire with a different elevation on the tangent sight. In indirect fire the same effect is produced by ordering a different quadrant elevation for each gun.

Rule for combined sights.

"Always use as many guns as possible, with 100 yards' differences if the error in range finding is probably considerable, and with 50 yards differences if the error in range finding is probably small."

Explanation of the result produced.

Example:—Range 1,500 yards (as found by range-finding instrument) 3 guns available.
50 yards differences will be used. (Rule above).

Then for direct fire, the order will be:—

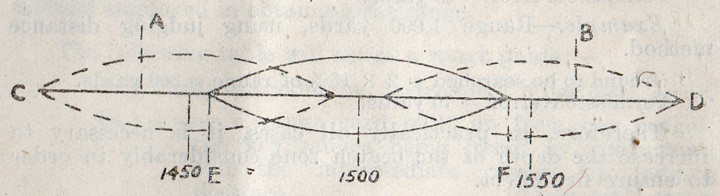
"1450 yards – 50 yards differences."

For indirect fire, the order will be:—

"Elevation 2° 5′ – 10′ differences.

(The angle of sight is assumed to be nil: the tangent elevation for 1,450 yards = 2° 5′, and that for 1,550 yards = 2° 25′.)

In each case the result at the target will be as follows:—



AB = 150 yards = Ground to be searched = (2 × 5% of range).

CD = Depth of E.B.Z. produced = 180 yards.

EF = Length of each E.B.Z. = 80 yards.

From this diagram it is clear that the likelihood of hitting the target (which lies between A and B) is greatly increased, but, as the fire is spread out, the density will be greatly diminished. Consequently, whenever observation of fire can be obtained, the controller must cease using combined sights, and fire with all the guns at the correct elevation to hit the target.

"Combined sights" is specially useful when surprise effect is desired, because each portion of the ground in which the target probably lies is beaten simultaneously.

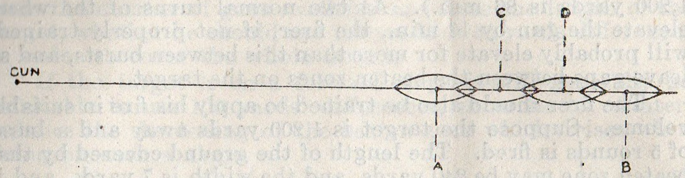
NOTE.—When the target is itself a depth of ground, *e.g.*, a wood, combined sights will be maintained, even though fire effect on a particular part of the target has been observed. (*See* para. 4 below.)

3. SEARCHING.

Definition:—The method of engaging any required depth of ground by applying successively overlapping zones of fire from one gun.

On comparing this method with combined sights, it will be seen that searching is of little value when surprise effect

is desired, because, whereas in combined sights each part of the target is engaged simultaneously, in searching each part of the target is engaged successively.

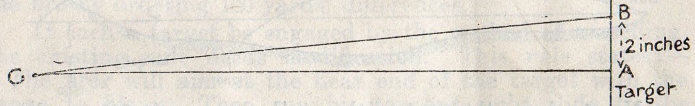


Suppose the target lies somewhere between the points A and B; then to ensure hitting it, the whole distance AB must be engaged.

The firer places a burst on A, then elevates his gun and places another on C, then on D, and continues until the whole line has been covered.

It requires much skill on the part of the firer to avoid gaps between bursts, and proficiency can only be obtained by constant practice on the 25 yards' range.

The firer is taught on the 25 yards' range to turn the elevating wheel after firing a burst, so that the next burst of fire is two inches above the first. This is called the "Normal" or "Two-inch" turn.



G is the gun position.

A and B the positions on the target of two bursts of fire, the necessary elevation being given to the gun after the first burst to raise the point of impact to B, which is two inches above A.

Using the V.I. formula:—

$$\text{The angle B.G.A.} = \frac{2 \times 3400}{25 \times 36} = 8 \text{ minutes (nearly)}$$

i.e., the two-inch turn elevates the gun eight minutes.

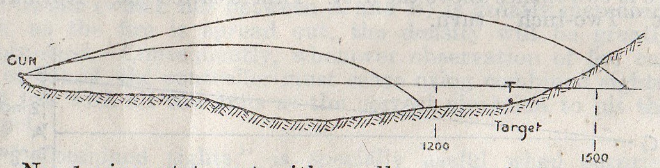
Alterations in elevation are made by turning the elevating wheel, and it must be impressed on the firer that the required turn is a very small one.

For example, when firing at 1,100 yards (tangent elevation 73 min.), an elevation of 13 min. will throw the beaten zone 100 yards forward (because the tangent elevation for 1,200 yards is 86 min.). As two normal turns of the wheel elevate the gun by 16 min., the firer, if not properly trained, will probably elevate for more than this between bursts, and so leave gaps between the beaten zones on the target.

The firer should also be trained to apply his fire in suitable volume. Suppose the target is 1,200 yards away and a burst of 5 rounds is fired. The length of the ground covered by that beaten zone may be 240 yards, and the width is 7 yards, and it is clear that the effect of 5 bullets on such a large area will be very small. Bursts of 20 or 30 rounds should be fired, or even more, if there is reason to suppose that the target is a dense one.

When searching is being employed to overcome errors in range-finding (the object at present under discussion) the following is the procedure:—

> The controller decides between what limits the target lies (say, between 1,200 yards and 1,500 yards).
>
> He then orders range to near limit (*i.e.*, 1,200 yards).
>
> Then he indicates the target.



No. 1 aims at target with smaller range (1,200 yards).
Controller then orders range to far limit (1,500 yards).
No. 1 alters his sights to 1,500 yards without elevating the gun.
No. 1 fires bursts and elevates until aiming at the target with 1,500 yards.

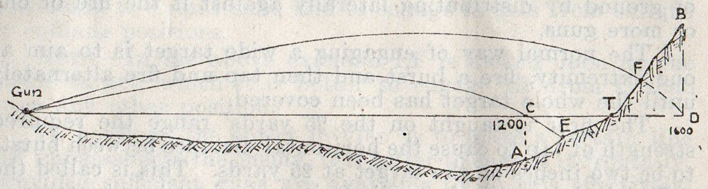
Then, providing that the target lay between 1,200 yards and 1,500 yards, it will have been effectively engaged.

4. There is also another important use of combined sights and searching, which arises when the target is itself longer than the beaten zone which can be produced by one gun.

In this case the total length of ground which must be searched can be found by adding the length of the target to twice the probable error.

When using combined sights, a point in the *centre* of the target will be employed as an aiming mark (if the centre is not visible, the near end), and the controller will decide from the number of guns available and from the length of the target, whether he should use 100 yards or 50 yards differences in order to cover the whole target.

If the target is on a forward slope it will generally be advisable to use 100 yards' differences, in order to counterbalance the shortening of the beaten zone which arises when firing on such a slope.



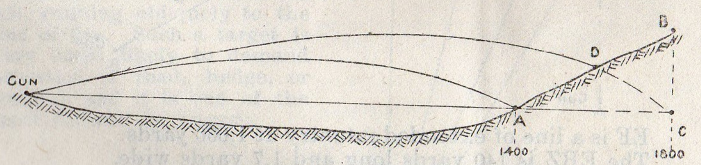
Example:—AB is a road, the near end being 1,200 yards and the far end 1,600 yards from the gun.

Then although a distance CD (400 yards) is covered *along the line of sight* (because all guns will have the same line of sight to T), only a part of the road AB will be covered, namely EF.

In order to cover as much of AB as possible, spread out the fire by ordering 100 yards' differences.

If such a target be engaged by the method of searching, the existing rule needs modification. This rule states:—"The firer will aim at the near end of the target with the range to hit it. Then run his tangent sight slide to the range to the far end. Then fire and elevate until aiming at the *near* end."

Such a process will only bring fire effect on the whole target when the far end of the target is on the prolongation of the line of sight to the near end.



Example:—AB is a long target on a forward slope, A being 1,400 yards, and B 1,800 yards from the gun. If the

existing rule be followed, the firer will elevate until aiming at A with 1,800 yards on his sights, but although his fire would, in the absence of ground at D, go to a point C, 1,800 yards along the line of sight, it will not touch B the far end of the target.

In such an instance the rule must be altered; the firer should fire and elevate until aiming at the *far* end of the target.

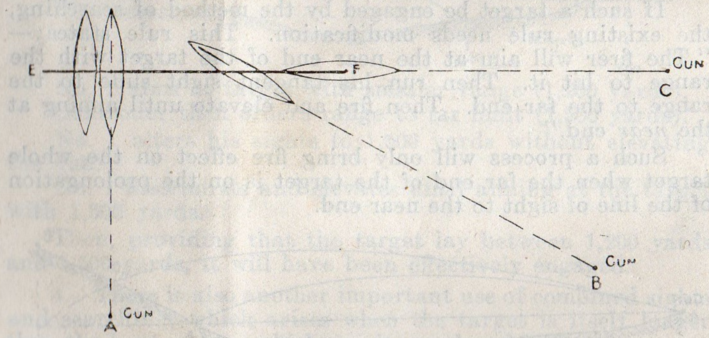
4. TRAVERSING.

Definition.—The method of engaging any required width of ground by distributing laterally against it the fire of one or more guns.

The normal way of engaging a wide target is to aim at one extremity, fire a burst and then tap and fire alternately until the whole target has been covered.

The firer is taught on the 25 yards' range the required strength of tap to cause the horizontal distance between bursts to be two inches on the target at 25 yards. This is called the "Regulation two-inch tap." It is equivalent to a traverse of eight minutes (*see* "Two-inch turn," page 35).

If the object in view is to bring fire effect on a belt or an area of ground (as in a barrage) this method is very effective. But if the target is a thin line of extended infantry, or a trench running at right angles to the line of fire, traversing is wasteful. In such cases the best fire effect is obtained by firing in enfilade, or as obliquely to the target as possible.



EF is a line of extended infantry at 1,000 yards.

The EBZ is 140 yards long and 1.7 yards wide.

Then if EF is engaged from A (*i.e.*, frontally), only the width of the EBZ can be counted as effective (1.7 yards).

If EF is engaged from C (*i.e.*, in enfilade), the whole length of the EBZ (*i.e.*, 140 yards) can be counted as effective. The fire effect produced will then be 80 times as effective from C as from A.

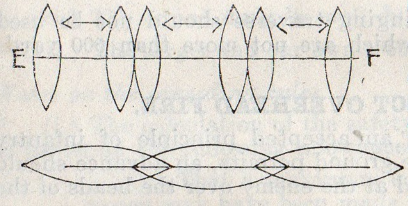
From B (*i.e.*, obliquely), the fire effect will be greater than from A, and the effect will increase the nearer the fire approaches to enfilade.

It will also be seen that the time taken to cover the whole Target EF from B will be much less from B than from A.

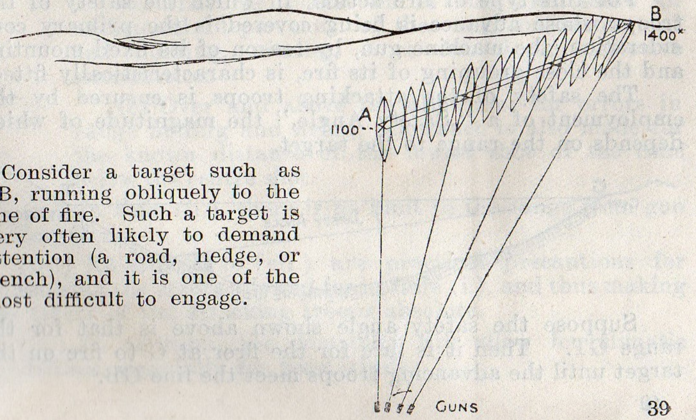
Every endeavour, therefore, should be made to reduce traversing to a minimum, and to engage targets from oblique or enfilade positions.

NOTE.—In the above example EF is looked upon as one single target, which it is better to engage EF from C than from any other position.

If, however, the object in view is to make a certain line EF impassable to the enemy, it is better to engage it frontally, provided sufficient guns are available to do this effectively, because then the enemy will be bound to pass through a deep belt of ground beaten by machine gun fire, whereas if the same object is attempted by enfilade guns, only a very narrow belt of ground is effectively engaged.



5. OBLIQUE TRAVERSING.



Consider a target such as AB, running obliquely to the line of fire. Such a target is very often likely to demand attention (a road, hedge, or trench), and it is one of the most difficult to engage.

The best way is to use a combination of combined sights, searching and traversing.

For example, with four guns, order:—

1,100 yards, 100 yards' differences.
Road—Four points of aim.
Oblique traversing.
Fire.

Each No. 1 will then traverse along his own portion of the target, keeping his line of sight on the target.

It will then be unnecessary to order any one gun to use different elevations.

6. SWINGING TRAVERSE.

This is a method of engaging a wide target by firing continuously, and at the same time distributing the fire along the whole target.

It necessitates loosening the traversing clamp, which allows the gun to vibrate more than in ordinary tap traversing, and it is therefore not so accurate as the normal method of traversing.

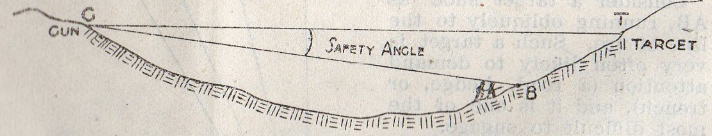
Consequently the swinging traverse should not be used except at dense targets which are not more than 500 yards distant.

7.—DIRECT OVERHEAD FIRE.

1. It has long been an accepted principle of infantry tactics that, whenever the ground permits, an advance should be assisted by fire directed at the enemy over the heads of the assaulting troops.

For this type of fire action, in which the safety of the troops whose advance is being covered is the primary consideration, the machine gun, by reason of its fixed mounting and the close grouping of its fire, is characteristically fitted.

The safety of the attacking troops is ensured by the employment of a "Safety Angle," the magnitude of which depends on the range to the target.



Suppose the safety angle shown above is that for the range GT. Then it is safe for the firer at G to fire on the target until the advancing troops meet the line GB.

2. RULES FOR DIRECT OVERHEAD FIRE.

(i.) If the range to the target is 1,000 yards or under, the safety angle is 30 min.

If the range to the target is between 1,000 and 1,500 yards, the safety angle is 60 min.

If the range to the target is over 1,500 yards, the safety angle is 100 min.

NOTE.—If the ground is comparatively flat between the gun and the target, closer support may generally be given by using the methods of indirect fire, if it is possible for these methods to be used.

(ii.) Direct overhead fire must not be employed if the attacking troops are more than 2,000 yards from the gun.

(iii.) The range to the target must be known to within 5 per cent.

(iv.) A worn barrel or a worn tripod must not be used.

(v.) No. 1 must be a good firer.

(vi.) The tripod must be well dug in.

(vii.) The target and our own troops must be clearly visible.

Notes on the preceding rules.

* (i.) The calculation of the safety angles given in Rule (i.) is based on the following allowances:—

(*a*) That a maximum error of 5 per cent. of the range may have been made in range-finding.

(*b*) That the lowest bullet may fall short an additional 10 per cent. of the range on account of bad holding, aiming, worn barrel or defective ammunition.

(*c*) Over and above the allowance for errors in range finding and firing, allowance is also made for the known distance of the lowest shot of the cone below the centre shot.

(ii.) In Rule (ii.), there is no limit to the range from gun to *Target*.

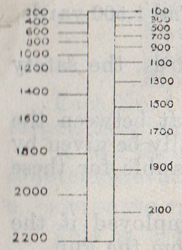
(iii.) Rules (iii.) to (vii.) are practical precautions for minimising the errors allowed for in Rule (i.), and thus making the safety of the attacking troops absolute.

(iv.) In addition, the controller will allow for climatic conditions, especially for head winds.

3. METHODS OF APPLYING SAFETY ANGLES.

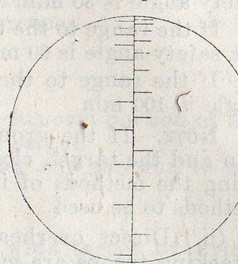
Method I.—By graticules.

Card.



(Card held at the distance denoted on the card from the eye.)

Field glasses.

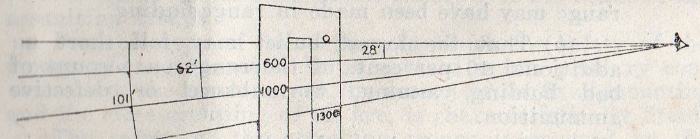


(View through graticuled glasses.)

It should be noticed at the outset that graticules were designed for indirect fire (*see* Sec. 9), and consequently the use of graticules for direct overhead fire is more or less accidental.

But it so happens that on looking through graticules (whether on a card or on graticuled glasses) the angle formed at the eye by the zero line and the 600 yards line is 28 min.

Similarly the angle between zero and 1,000 is 62 min., and the angle between zero and 1,300 yards is 101 min.



These three angles are very close approximations to the angles laid down in Rule 1, and the error involved in using them as 30 min., 60 min. and 100 min. is negligible.

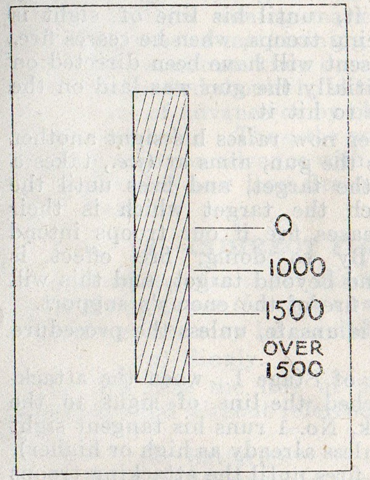
The procedure is to align the graticule so that the line from the controller's eye through the zero mark is on the target.

Then the line passing through the 600 yards' graticule will give the safety limit when the range to the target is 1,000 yards or under (*i.e.*, safety angle of 28 min.).

The line passing through the 1,000 yards graticule will give the safety limit when the range to the target is between 1,000 and 1,500 yards (*i.e.*, safety angle of 62 min.).

The line passing through the 1,300 yards graticule will give the safety limit when the range to the target is more than 1,500 yards (*i.e.*, safety angle of 101 min.).

Method II.—Special safety angle graticule card.



The card is aligned so that the line from the controller's eye through the zero mark is on the target. Then the line marked "1,000" will give a safety angle of 30 min. The line marked "1,500" will give a safety angle of 60 min., and the line marked "over 1,500" will give a safety angle of 100 min.

(Card held at the distance denoted on the card from the eye.)

The controller, observing Rule 1, and knowing the range to the target, will know which line to use for any particular instance.

Method III.—Tangent sight method.

In the two methods given above, the controller alone knows how far it is safe to support the advance. If he should become a casualty, the firer will be in danger either of supporting the advance beyond the safety limit, or of ceasing fire too soon, in which case the attacking troops will lose the effect of his covering fire.

A second objection to the two previous methods is that only three safety angles are permissible. This in itself is

unsound, because the safety angle necessarily varies with every variation in the range.

Both difficulties are overcome by the following method:—

Stage I.—The firer lays on the target with the range to hit it. Then, without moving the gun, he runs up his sights 300 yards higher, and finds at which point on the ground he is now aiming.

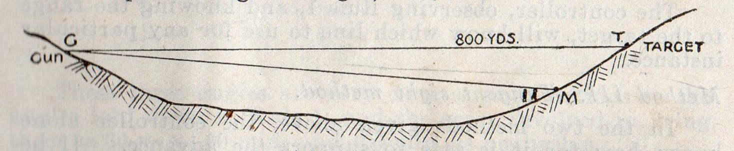
This position on his new line of sight becomes his aiming mark, and he continues firing, constantly checking his aim on it, until his line of sight is touched by the advancing troops, when he ceases fire. The fire up to the present will have been directed on the target, because initially the gun was laid on the target with the range to hit it.

Stage II.—The firer now raises his sight another 200 yards and elevates the gun, aims at (*i.e.*, takes a line of sight on to) the target, and fires until the attacking troops reach the target which is their objective, when he ceases fire if our troops intend advancing further. By so doing, fire effect is produced on the ground beyond target, and this will help to neutralize the fire of the enemy's support.

At close ranges Stage II. is unsafe, unless the procedure is modified as follows:—

At the completion of Stage I., when the attacking troops have touched the line of sight to the auxiliary aiming mark, No. 1 runs his tangent sight slide to 1,300 yards (unless already as high or higher), lays on the target and fires until the attacking troops reach the target.

Example:—Range to target, 800 yards.



Lay on the target with 800 yards on the sights.

Alter tangent sight to 1,100 yards (*i.e.*, 300 yards higher), use the point M thus found, as aiming mark.

Fire until the attacking troops touch the line G.M.

Then cease fire, *and set sights at 1,300 yards.*

Aim at the target, and continue firing until the advancing troops reach T. Then cease fire.

4. CONCLUSION.

In the absence of factors which obstruct the field of view (mist, smoke screens, the smoke and dust caused by artillery, etc.), the foregoing methods of direct overhead fire are technically reliable. But because one or other of these factors either is or may be present, arrangements for indirect fire should be made as stated in Part I., Section 15, and they should be of the following nature:—

Once the gun has been laid on the target, an auxiliary aiming mark should be put out for the purpose of maintaining elevation and direction, and the maximum time during which the advance can be supported should be obtained either by estimating the rate of advance or by obtaining it from the artillery time-table. Thus, the point up to which the attacking troops can advance with safety being known, it can be decided how long fire may safely be directed on the target.

8.—INDIRECT FIRE (GENERAL).

1. *Indirect fire is fire directed by any other means than laying the gun over the sights on to the target.*

Indirect fire may be carried out by guns controlled:—

(*a*) Singly.

In this case the line of fire of each gun is laid out separately, and without reference to the line of fire of another gun.

(*b*) Batteries.*

In this case the lines of fire of the guns constituting the battery are laid out in parallel directions, and these form a basis from which the controlling officer can issue an order producing:—

(*a*) Distribution of fire along any line.

(*b*) Concentration of fire on any locality.

Where possible, registration should always be carried out.

As this is often impossible, reliance must be placed upon the theoretical rules which underlie the application of indirect fire.

Unless these rules, their limitations and applications are clearly understood, accurate indirect fire is impossible, the safety of the troops, over whose heads the fire is being directed,

* See Note at end of Index.

may become endangered, and the expenditure of S.A.A. is not justified.

For example, unless the officer carrying out the fire has a knowledge of his probable errors in direction and elevation, he may either:—

(*a*) By searching an area unnecessarily large (in order to obtain fire effect on the target) obtain a very small material result; or

(*b*) By searching an area too small, miss the target altogether.

If the necessary care is taken, accurate indirect fire can be carried out with the present equipment of the gun.

In order to test this possibility, tests have been carried out over a period of six months. These have been undertaken by different squads of officers under instruction, under varying weather conditions.

The targets were six 10 ft. by 3 ft. screens placed one behind the other, but on the side of a hill, so that one shot could not hit more than one target. The map location of the targets was given to the officers carrying out the test.

In all cases elevation was placed on the gun by clinometer and one belt was fired.

No traversing was allowed, as the tests were designed to show the errors in direction.

The following results were obtained:—

Gun position fixed by detail on the map.

Range, 1,200 yards.

I.—Direction by compass.

No. of tests, 20. Average error in direction, 30 min.

II.—Direction by reference object.

No. of tests, 22. Average error in direction, 15 min.

Gun position fixed by resection.

No points nearer than 1,000 yards were allowed to resect from.

Range, 1,450 yards.

III.—Direction by compass.

No. of tests, 17. Average error in direction, 15 min.

IV.—Direction by reference object.

No. of tests, 21. Average error in direction, 30 min.

The results show that with care the degree of error should not exceed 30 min., therefore a total traverse of 1 deg. should include the target.

To carry out indirect fire with accuracy and rapidity entails a high standard of professional efficiency on the part of the officer. He must have a thorough knowledge of:—

(*a*) Maps.
(*b*) The compass and its "characteristics."
(*c*) The tables and graphs which give—
  (i.) Angles of elevation and descent.
  (ii.) Dimensions of cones and beaten zones.
  (iii.) Methods of determining quadrant elevation.
  (iv.) Methods of determining clearances.
  (v.) Allowances for atmospheric conditions.
(*d*) Methods of laying and fire control.
(*e*) The technical equipment in use.
(*f*) Probable errors.

2. Indirect fire will be dealt with under the following headings:—

Indirect fire of guns controlled singly.

I. Without the map (*i.e.*, where a 1/20,000 or larger scale contoured map is not available).
(*a*) By graticules.
(*b*) By angle of sight instrument or director.

II. With the map (*i.e.*, where a 1/20,000 or large scale contoured map is available).
(*a*) To obtain direction.
(*b*) To obtain elevation.

Indirect fire of guns controlled in batteries.

I. With the map.
II. Without the map.

Maintaining laying.
Clearances.
Night firing.
Searching reverse slopes.
Errors.
Barrage fire.

9.—INDIRECT FIRE OF GUNS CONTROLLED SINGLY.

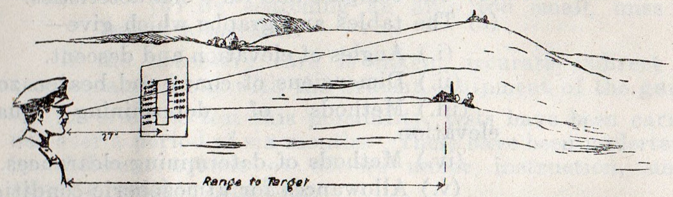
1. INDIRECT FIRE WITHOUT THE MAP.

A. *By use of graticules.* (*See* Sec. 7.)

The following instruments are required:—

(i.) Barr and Stroud range-finder.

(ii.) Field glasses in which graticules are cut across the focal plane, or graticule cards.



Procedure.

(i.) Move to a position from which the target can be observed. (This should not be more than 6 feet above the gun, and at approximately the same range from the target.)

(ii.) Obtain range to target.

(iii.) Select a suitable aiming mark, visible to the gun, which is vertically above or below the target, and in alignment of gun and target.

(iv.) Observe the target so that the graticule representing the range falls across the target.

(v.) Note which graticule cuts the aiming mark, and the corresponding range.

(vi.) Order the No. 1 of the gun to put this range on his tangent sight and lay on the aiming mark.

This method gives accuracy of direction but not great accuracy of elevation. The fire effect is greatly enhanced when observation can be obtained.

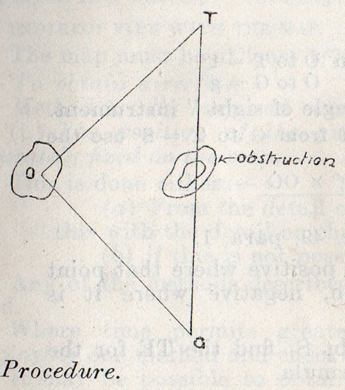
NOTE 1.—As the range on the sight is not the range to the target, the fire cannot be corrected by ordering " up 50 " or " down 50," etc. (since the ratchet is uniform, and an alteration of one click elevates or depresses the gun through the same angle, no matter what position of the slide, the correction is applied by alteration by clicks).

There are roughly as many clicks in the ratchet of the tangent sight as there are hundreds of yards in the range, at all ranges below 1,500 yards.

For example, if the range is 1,200 yards, and fire is 100 yards short, the controlling officer orders " up 12 clicks." The No. 1 moves his slide up 12 clicks and relays on the auxiliary aiming mark.

NOTE 2.—Where a suitable auxiliary aiming mark can be seen above or below the target, this method is useful to bring fire to bear on a target which is visible through glasses, and is difficult to indicate to the No. 1.

B. *By the TOG method.*



The figure shows the Gun position, G. Target position, T. Observation station, O.

The following instruments are required:—

1. Barr and Stroud range-finder.
2. Director and angle of sight instrument, or some means of measuring the angle TOG and angles of sight.

Procedure.

To obtain direction:—

After selecting the gun position the Controlling Officer goes to a position from which he can see both the gun and the target, and—

(1) Takes ranges to the gun and to the target with the Barr and Stroud.

(2) Measures the angle TOG.

This is done:—

(*a*) With a director, by laying it on G and T in turn, and noting the angle swung through.

(*b*) Without a director by taking bearings to G and to T, and then the difference between these bearings is the angle TOG.

The ranges OT, OG, and the angle TOG being known, it is now simple to find the range GT, and the angle TGO.

This is done:—

(*a*) With the "plotter."

(*b*) Without the "plotter." Draw a line to represent the range OT, set off the angle TOG with a protractor, and mark off the point G, so that OG represents the range OG. Measure the angle TGO with the protractor.

Order the gun to lay on the observation station and lay off the angle TGO. An aiming post is now set out, and the gun is laid for direction.

To obtain elevation:—

Take the angle of sight from O to T = t°
O to G = g°

This is done with an "angle of sight" instrument.

To find the angle of sight from G to T = S° use the formula:—

$$S^\circ = \frac{t^\circ \times OT - g^\circ \times OG}{GT}$$

NOTE.—*See* Theory of Fire, Sec. 49, para. 1.

The angle of sight to a point is positive where that point is above the position of observation, negative where it is below.

Having found the angle of sight S, find the TE for the range GT and the Q.E. from the formula.

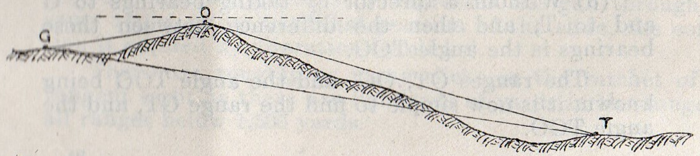
$$Q.E. = T.E. \pm S.$$

Order this Q.E. to be placed on the gun.

The gun is now laid for direction and elevation. Where observation can be obtained fire can be corrected by ordering "30 min. left," etc. – "up 20 min."

The fire control is best carried out by telephonic communication from O to G—or where this is not possible, by visual signalling.

Where the observation post is in the direct line from the gun to the target, direction can be obtained by placing posts, and elevation as follows:—



Let:—

OT = Range from crest to target.
OG = Range from crest to gun.
t° = Angle of sight from crest to target.
g° = Angle of sight from crest to gun.

Then angle of sight from gun to target = S°

$$S^\circ = \frac{t^\circ \times OT - g^\circ \times OG}{GT}$$

and GT = OG + OT approximately.

This "TOG" method can be easily adapted to guns employed in a battery. (*See* Sec. 10, para. 5.)

2. INDIRECT FIRE WITH THE MAP.

The map must be at least 1/20,000 and contoured.

A. *To obtain direction.*

Method 1. *By map and compass.*

(i.) *The position of the gun on the ground must be accurately fixed on the map.*

This is done either:—

(*a*) From the detail on the ground and comparing this with the detail on the map; or

(*b*) if this is not possible, by resection.

Any of the methods described in Sec. 2, para. 2, may be used.

Where time permits greater accuracy is ensured by employing one method and checking with another.

It may be possible to obtain the aid of a Field Survey Company where a very accurate location is necessary.

The use of oblique aeroplane photographs has been found helpful when moving guns forward to positions already sited in territory previously hostile.

(ii.) *The magnetic bearing from the gun to the target must now be found.*

To do this:—

(*a*) Draw a line on the map from the gun position to the target.

(*b*) Using the protractor, measure the bearing this line makes with any North and South Grid line. This is the grid bearing from the gun to the target.

(*c*) Add the magnetic variation of the compass from the North and South Grid lines. The result is the magnetic bearing from the gun to the target.

NOTE 1.—(*c*) Applies only to places where the magnetic variation is West.

If the variation is East, subtract instead of add.

NOTE 2.—The variation of the compass must be determined for each compass for the particular map in use, and should be constantly checked. (*See* Sec. 2, para. 2.)

(iii.) *To lay the gun on the magnetic bearing so obtained.* This can be done in the following ways:—

(*a*) Place a post (not more than 6 inches high) in the gun position and place the compass on the top of the post. Rotate the compass until the card reads the required bearing.

Align an aiming post on this bearing using the hair line on the compass. Place the gun with the centre of the cross at the bottom of the socket, immediately over the post, and lay on the aiming post.

(*b*) By use of the compass tower.

See Appendix VIII.

(*c*) It may often be impossible owing to the presence of iron to use a compass from the gun position itself. Take the compass out more or less in the required line of fire, either in front of, or behind the gun.

Two cases now occur:—

1. *Compass in front of gun.*

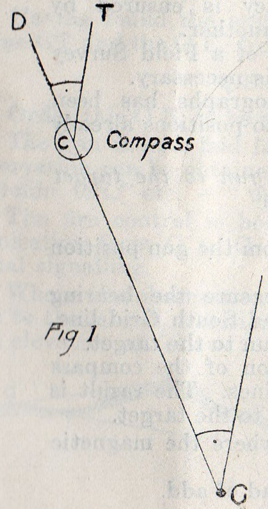


Fig 1

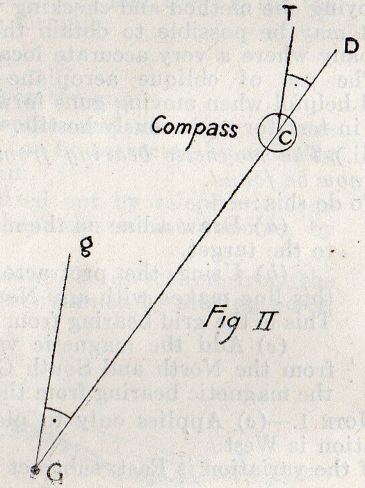


Fig II

The figures shew:—

1. CG the bearing from compass to gun.
2. CD the back bearing.
3. CT the bearing on which the gun is required to fire.
4. Gg the line of fire obtained by laying off the angle gGC, which = the angle TCD.

NOTE.—Since the angle gGC = the angle TCD gG is parallel to CT, and the gun is laid on the bearing required.

Rule.

1. Take the compass 30 to 50 yards in front of the gun more or less in the direction of fire. Lay the gun on the compass. Take the bearing CG on to the gun.

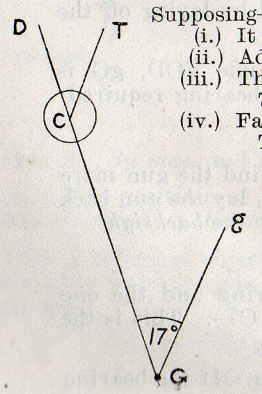
2. Obtain the back bearing CD.

3. Obtain the angle between this bearing and the one on which it is required to lay the gun (*i.e.*, CT). This is the angle TCD.

4. The observer at C now turns his back on the gun, and faces the direction CD—if the bearing on which it is required to fire the gun (*i.e.*, CT) lies to his right, the gun lays off the angle TCD to the right—and if to his left, the angle TCD is laid off to the left.

The gun is now laid on the required bearing in the direction Gg, which is parallel to CT; and an aiming post is put out.

Example:—To lay a gun on a magnetic bearing of 7 deg.



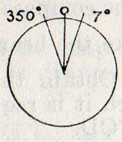
Supposing—

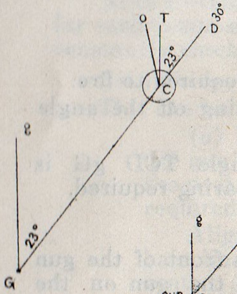
(i.) It is found that bearing CG = 170°.

(ii.) Adding 180° the back bearing CD = 350°

(iii.) The difference between a bearing of 350° and 7° = 17°.

(iv.) Facing CD the bearing CT lies to the right. Therefore the gun lays off 17° to the right,





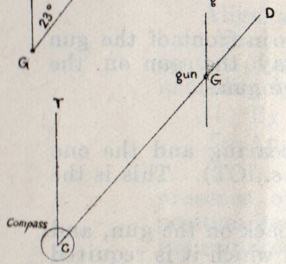
Or again it may be found that—

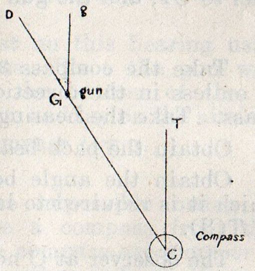
(i.) Bearing CG = 210°.

(ii.) Subtracting 180° the back bearing CD = 30°.

(iii.) The angle TCD = 30° − 7° = 23°.

(iv.) Facing CD the bearing CT lies to the left; therefore the gun lays off 23° to the left.





Compass behind gun.

The figures shew:—

(i.) CG the bearing from compass to gun.

(ii.) CT the bearing on which the gun is required to fire.

(iii.) Gg the line of fire obtained by laying off the angle gGD, which = the angle TCD.

NOTE.—Since the angle gGD = the angle TCD, gG is parallel to CT, and the gun is laid on the bearing required.

Rule.

1. Take the compass 30 to 50 yards behind the gun more or less in the prolongation of the line of fire, lay the gun back on to the compass from the *foresight* through the *backsight*.

Take the bearing CG on to the gun.

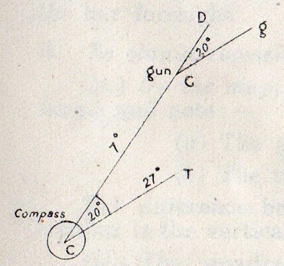
2. Obtain the angle between this bearing and the one on which it is required to lay the gun (*i.e.*, CT). This is the angle TCD.

3. The observer at C, now faces the gun. If the bearing

on which it is required to fire the gun lies to his right, the gun lays off the angle TCD to the right—and if to his left, the angle TCD is laid off to the left.

The gun is now laid on the required bearing in the direction Gg, which is parallel to CT; and an aiming post is put out.

Example:—To lay a gun on a magnetic bearing of 27 deg.

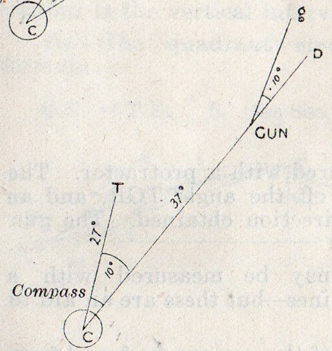


Supposing:—

1. It is found that bearing CG = 7 deg.

2. Difference between a bearing of 27 deg. (*i.e.*, CT) and 7 deg. = 20 deg.

3. Facing CD the bearing CT lies to the right, therefore the gun lays off 20 deg. to the right.



Or, again, it may be found that:—

1. Bearing CG = 37 deg.

2. Difference between a bearing of 27 deg. (*i.e.*, CT) and 37 deg. = 10 deg.

3. Facing CD the bearing CT lays to the left, therefore the gun lays off 10 deg. to the left.

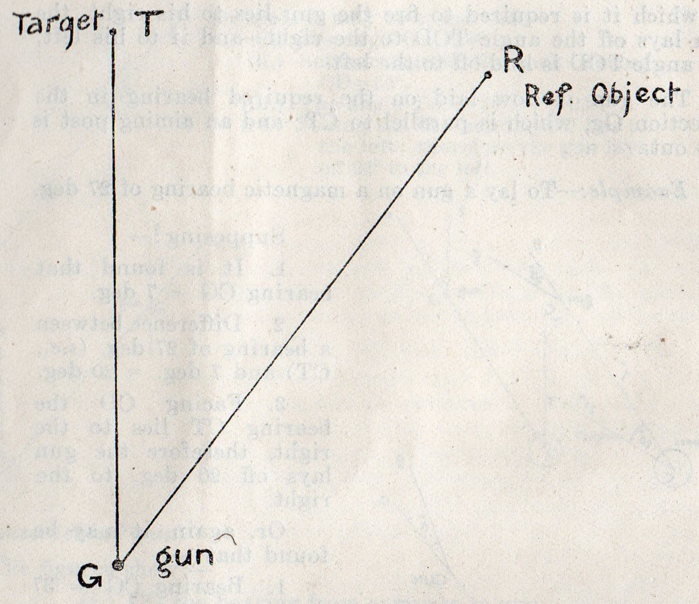
Method 2. By map and reference object.

(i.) The position of gun on the ground must first be accurately fixed on the map. (*See* Sec. 2, para. 2.)

(ii.) A reference object, which is both marked on the map and visible from the gun, is next selected. A line is drawn on the map.

(*a*) from the gun position to the target—G.T.; and

(*b*) from the gun position to the R.O. —G.R.



The angle TGR is now measured with a protractor. The gun lays on the R.O. and taps off the angle TGR, and an aiming post is put out in the direction obtained. The gun is now aligned on the target.

NOTE 1.—The angle TGR may be measured with a protractor without drawing any lines—but these are an aid to accuracy.

NOTE 2.—Where the position of the gun can be found from the detail on the ground, all errors arising from the use of the compass are avoided.

Method 3. By map, reference object, and compass.

A modification of Method 2 is necessary where no suitable reference object exists which is marked on the map and is visible from the gun.

Select a reference object on the ground, or, if necessary, place one out. Take the compass bearing from the gun position to the reference object.

Find from the map the bearing on which it is required to fire the gun. Find the difference between these bearings and lay off the angle obtained from the reference object.

NOTE.—*Effect of atmospheric conditions on direction.*

After the gun has been laid for direction by any of the methods given above, it is necessary to make the correction for wind. To find the allowance *see* Sec. 5, para. 3.

This allowance is put on the gun either by tapping off the required angle on the "T" shaped aiming post or by using the bar foresight.

B. *To obtain elevation.*

(i.) *On the map*, measure the range from the gun to the target and note:—

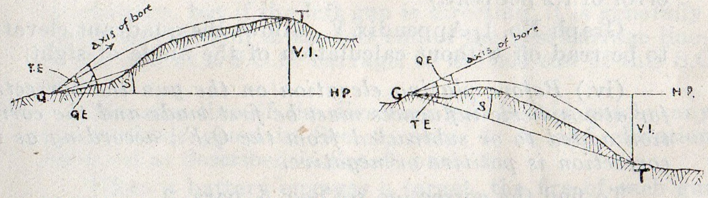
(*a*) The gun contour.

(*b*) The target contour.

The difference between the gun contour and the target contour is the vertical interval (V.I.).

(ii.) The quadrant elevation is now found by the formula:—

$$\text{Q.E.} = \text{T.E.} \pm \text{S.} \quad (\textit{See } \text{Sec. 5, para. 1.})$$



To obtain the angle of sight use the formula:—

$$\text{Angle of sight in minutes} = \text{S} = \frac{\text{V.I.}}{\text{H.E.}} \times 3400,$$

where V.I. = Vertical interval,
H.E. = Range,

and both are measured in the same unit.

In France, where the vertical intervals are in metres and the ranges in yards, the following may be used:—

$$\text{S (in minutes)} = \frac{\text{V.I. (metres)}}{\text{H.E. (yards)}} \times 3750.$$

Example:—

Range = 1,700 yards and T.E. for 1,700 = 177′.
Gun contour = 20 yards.
Target contour = 50 yards. Therefore V.I. = 30.

$$S = \frac{30}{1700} \times 3400 = 60'.$$

$$\begin{aligned} QE &= TE + S \\ &= 177 + 60 = 237', \end{aligned}$$

or again if range = 1,700 yards,
Gun contour = 50 yards,
Target contour = 20 yards,

$$S = \frac{30}{1700} \times 3400 = 60'$$

$$\begin{aligned} QE &= TE - S \\ &= 177' - 60' \\ &= 177'. \end{aligned}$$

(iii.) In order to save calculating the angle of sight and combining it with the tangent elevation to find the quadrant elevation, Tables 3A and 3B (Appendix IV.) have been compiled.

(These tables are compiled from the formula:—

$$S = \frac{\text{V.I.}}{\text{H.E.}} \times 3438:$$

the factor 3438 being more accurate than 3400, which gives an error of 1.2 per cent.)

Graph No. 1, Appendix V., allows the quadrant elevation to be read off without calculation of the angle of sight.

(iv.) *Before placing elevation on the gun the correction for atmospheric influences must be first made and the correction added to or subtracted from the Q.E., according as the correction is positive or negative.*

To find the correction *see* Sec. 5, para. 3.

(v.) *To put the elevation on the gun.*

Elevation is put on the gun with the clinometer:—

(*See* Appendix XI.: Adjustment of clinometers).

1. Set the clinometer to the required reading.
2. *Without holding*, place the clinometer on the tangent sight bed and elevate or depress the gun until the bubble is central. Move up the tangent sight slide until the point of aim is on the auxiliary aiming mark.

3. Take the holding and relay on the auxiliary aiming mark, using the elevating wheel, and *not* moving the tangent sight slide.

NOTE.—This method obviates the error arising from a difference in holding when putting on elevation and when firing.

10.—INDIRECT FIRE OF GUNS CONTROLLED IN BATTERIES.*

Laying and fire control where 1/20000 or larger scale contoured map is available.

(To be read in conjunction with Barrage Drill, Sec. 17, para. 7.)

1. All the guns of one battery are laid on parallel lines of fire initially, and zero aiming posts are placed in position. These lines are called the zero lines of fire of the battery, and form the basis from which the line of fire of each gun is taken. The methods of obtaining parallel lines of fire are explained in para. 4 of this Section, but where the nature of the ground admits, these lines should be checked by registration.

The guns are numbered from right to left, and the position of one gun is fixed as accurately as possible on the map. This gun is known as the directing gun, and is generally the left gun, to facilitate control. The choice of the zero line is arbitrary, but if the left gun is directing, it is generally the line from that gun to the left end of the first barrage line—or in the case of a S.O.S. barrage, to the left end of this S.O.S. line.

The zero line of the directing gun is laid out by any of the methods given in Sec. 9, para. 1, A, and elevation is obtained as described in Sec. 9, para. 2.

When a battery engages a target, the fire of each gun is laid at equal intervals along it. Each gun traverses 1 deg. either side of its line of fire, except:—

(i.) When concentrated fire is ordered.

(ii.) Where the concentration of guns is great, *i.e.*, one gun to between 30 and 40 yards of front, when the total traverse is 1 deg.

(iii.) Where the concentration of guns is thin, and a traverse of 1 deg. either side is insufficient to ensure that no gaps are left. In this case a traverse of twice the angle of distribution should be ordered.

* *See* note at end of Index.

This traverse prevents gaps by causing :—

(i.) The fire of neighbouring guns to overlap.

(ii.) The fire of neighbouring batteries to overlap.

At the same time, as the angle of traverse is small, different guns can have different quadrant elevations when the nature of the target demands it.

The fire is controlled by either—

(*a*) Shutter.

(*b*) Whistle.

The former has been found the more effective method.

2. DISTRIBUTION OF FIRE.

Where the frontage of the target as viewed from the battery, is greater than that of the battery, it is necessary to distribute the fire of the battery from their parallel lines, in order to lay the fire of each gun at equal intervals along the target.

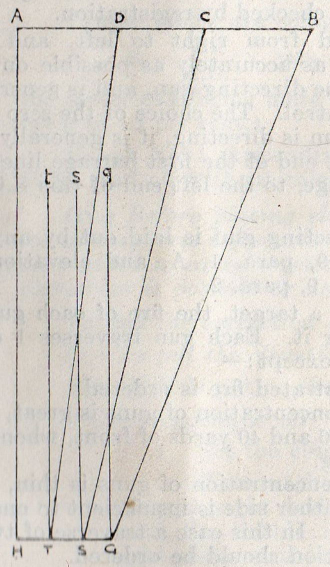


Fig. I. (not to scale).

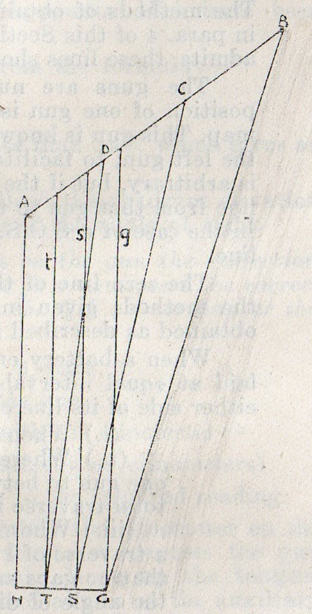


Fig. II. (not to scale).

These figures shew the lines of fire of a 4-gun battery :—

(*a*) On their parallel zero lines.

(*b*) After distribution of fire along :—

(i.) A frontal target.

(ii.) An oblique target.

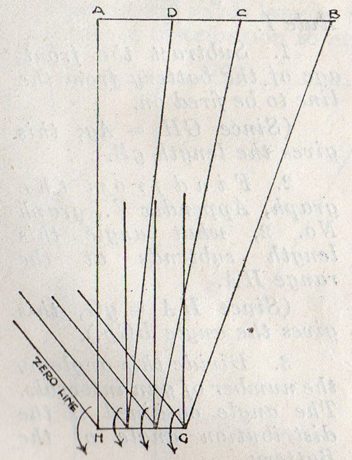
The angle DTt is the *angle of distribution of the battery for the target AB.*

The angle CSs = twice the angle DTt.
The angle BGg = three times the angle DTt.

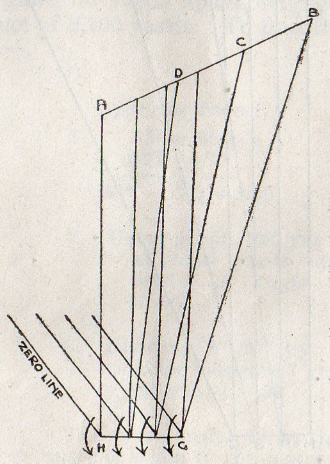
Example :—If angle DTt = 1°
angle CSs = 2°
angle BGg = 3°

Measurements of this angle are taken to the nearest 10 min.

If the zero line of the left gun (*i.e.*, directing gun), is not directed on the left end of the target, this gun is switched through an angle so as to direct its fire on to the left end of the target. This angle is called the " switch angle," and before distribution of fire along the target, all guns are ordered to lay off this angle from their zero lines. This angle is measured by a protractor, or read from the fighting map.



Angle of switch.
Fig. III. (not to scale).



Angle of switch.
Fig. IV. (not to scale).

These figures shew the lines of fire of a 4-gun battery :—

(*a*) On their parallel zero lines.

(*b*) After all guns lay off the " angle of switch " from their zero lines.

(The guns are still on parallel lines of fire.)

(*c*) After distribution of fire along :—

(i.) A frontal target.

(ii.) An oblique target.

To obtain the distribution angle.

Case I.

Frontal barrage.—Where the angle HAB is between 80 deg. and 100 deg.

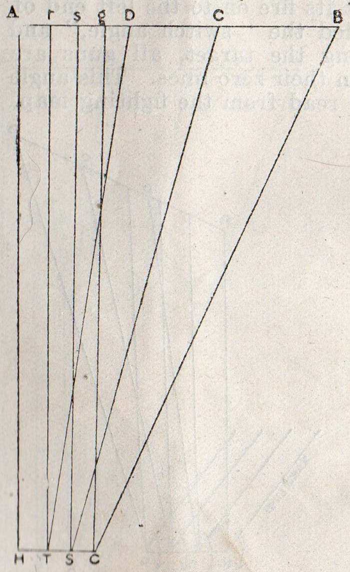


Fig. V. (not to scale).

The figure shews the guns of a 4-gun battery.

(*a*) On parallel lines before distribution.

(*b*) After distribution on the target AB.

Rule I.

1. *Subtract the frontage of the battery from the line to be fired on.*

(*Since GH = Ag, this gives the length gB.*)

2. *Find from the graph, Appendix V., graph No. 2, what angle this length subtends at the range HA.*

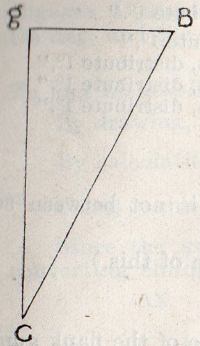
(*Since HA = gG, this gives the angle BGg.*)

3. *Divide this angle by the number of gun intervals. The angle obtained is the distribution angle of the Battery.*

(See *para. 2 above.*)

If no graph is available the angle BGg can be obtained :—

(i.) By using the " angle of sight " formula.



$$\frac{\text{V.I.}}{\text{H.E.}} \times 3400 = \text{angle in minutes.}$$

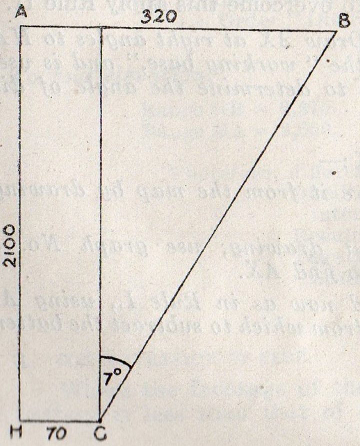
Where V.I. = AB − GH = gB.
H.E. = Range HA = gG.

NOTE.—This formula should not be used if the angle BGg exceeds 10 deg.

Fig. VI.

(ii.) By measurement with a protractor. *No* lines need necessarily be drawn, but errors are easily made in measuring the angle BGg.

Example:—A battery of 8 guns, 10 yards apart, engages a target 320 yards long at a range of 2,100 yards. To find the angle of distribution to order :—



Applying Rule I.

1. AB = 320
GH = 70
AB − GH = 250

2. Using graph, 250 yards at 2,100 yards subtends an angle of 6° 50′.

3. Dividing 6° 50′ by 7 (since there are 7 gun intervals) = 59′.

Therefore, order 1°, as the angle is taken to the nearest 10′.

Fig. VII. (Not to scale.)

NOTE.—(i.) As the angle HAB is between 80° and 100°, this is a frontal barrage.

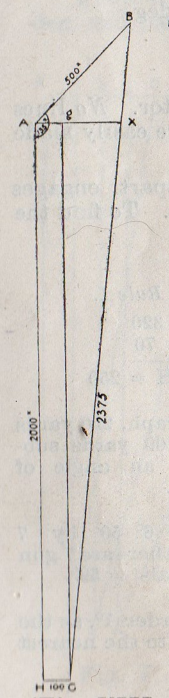
(ii.) On the order being given :—" Distribute 1°."

No. 1 of No. 8 gun repeats " Distribute 1°,"
No. 1 of No. 7 ,, ,, " 1° right, distribute 1°,"
No. 1 of No. 6 ,, ,, " 2° right, distribute 1°,"
No. 1 of No. 5 ,, ,, " 3° right, distribute 1°,"
etc. (*See* Barrage Drill, Third stage.)

Case II.

Oblique barrage.—Where angle HAB is not between 80 deg. and 100 deg.

(NOTE.—Enfilade barrage is only a type of this.)



(Fig. VIII. to scale).

The figure shows :—

(*a*) The parallel lines of fire of the flank guns of a battery before distribution.

(*b*) The lines of fire of the flank guns after distribution on an oblique target.

It is obvious that if Rule I. is applied, the distribution would be inaccurate owing to the foreshortening of the target when viewed from the battery. To overcome this apply Rule II.

Rule II. Draw AX at right angles to HA. This is called the " working base," and is used instead of AB to determine the angle of distribution.

To find AX :—

(*a*) *Measure it from the map by drawing, or,*

(*b*) *Without drawing, use graph No. 2, Appendix V. to find AX.*

(*c*) *Proceed now as in Rule I., using AX instead of AB from which to subtract the battery frontage.*

NOTE.—As the ranges HA and GB are different, combined sights are used.

Example:—An 8-gun battery on a front of 100 yards, engages a target 500 yards long, where the angle HAB = 135 deg. and the range HA = 2,000 yards. (*See* Fig. VIII.)

To find the angle of distribution.—Apply Rule II.

By drawing, the working base AX = 320 yards.

By calculation :—

Using graph No. 2.

Since the angle HAB = 135°, then from the scale for converting oblique to equivalent frontal targets

$$\begin{aligned} AX &= \cdot 64 \times AB \\ &= \cdot 64 \times 500 \\ &= 320 \text{ yards.} \end{aligned}$$

Proceeding now as in Rule I. and using AX instead of AB,

(i.)
$$\begin{aligned} AX &= 320 \\ GH &= 100 \\ \therefore AX - GH &= 220. \end{aligned}$$

(ii.) 220 yards and 2,000 yards subtends 380′

(iii.) dividing 380′ by 7 (as there are 7 gun intervals) = 54′ *i.e.* Order " Distribute 50′."

To find elevation.

Range GB = 2,375. QE = 390′
Range HA = 2,000. QE = 256′

Therefore, difference = 134′.

Dividing by 7 (*i.e.*, the number of gun intervals)

Result = 19′.

Take 20′, being to the nearest 10′, and order "Elevation 4° 20′, 20′ differences."

3. CONCENTRATION OF FIRE.

Where the frontage of the target as viewed from the battery is less than that of the battery, it is necessary to

concentrate the fire of the battery from their parallel lines.

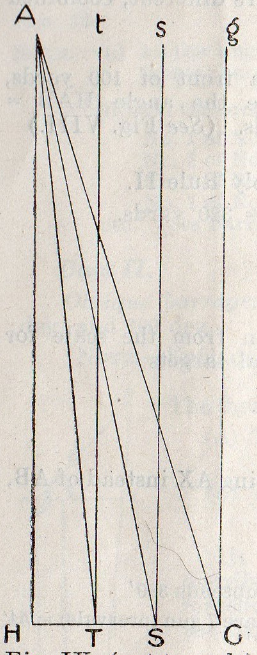


Fig. IX. (not to scale).

This figure shows the lines of fire of a 4-gun battery.

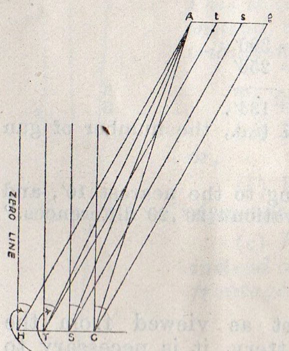
(*a*) On their zero lines.

(*b*) After concentration on the target A.

The angle tTA is the angle of concentration of the battery for the target A.

The angle sSA = twice the angle tTA.

The angle gGA = three times the angle tTA.



Angle of switch.

Fig. X. (not to scale).

This figure shows the lines of a 4-gun battery.

(*a*) On their zero lines.

(*b*) After all guns lay off the "angle of switch" from their zero lines. (*See* para. 2, Figs. III. and IV.)

(*c*) After concentration on to the target A.

The angle tTA is the angle of concentration of the battery for the target A.

The angle sSA = twice the angle tTA.

The angle gGA = three times the angle tTA.

To find the angle of concentration.

Rule III.

Subtract the frontage of the target from the frontage of the battery, and proceed exactly as in Rule I., but substitute concentration for distribution.

Example :—A battery of 8 guns on a frontage of 120 yards desires to engage a target whose frontage is 40 yards, at a range of 2,100 yards. To find the angle of concentration.

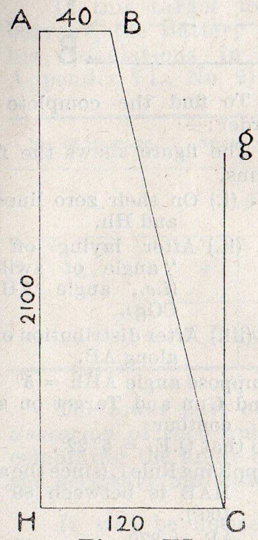


Figure XI.

(i.) GH = 120 yards
AB = 40
GH − AB = 80

(ii.) 80 yds. at 2,100 subtends an angle of 2° 15′

(iii.) Dividing by 7, Result = 19′.

Order 20′ as angle of concentration.

NOTE 1.—On order being given, " Concentrate 20 min.,"

No. 1 of No. 8 gun repeats, " Concentrate 20′."
No. 1 of No. 7 ,, "20′ left, concentrate 20′,"
No. 1 of No. 6 ,, "40′ ,, ,, 20′,"
No. 1 of No. 5 ,, "1° ,, ,, 20′,"

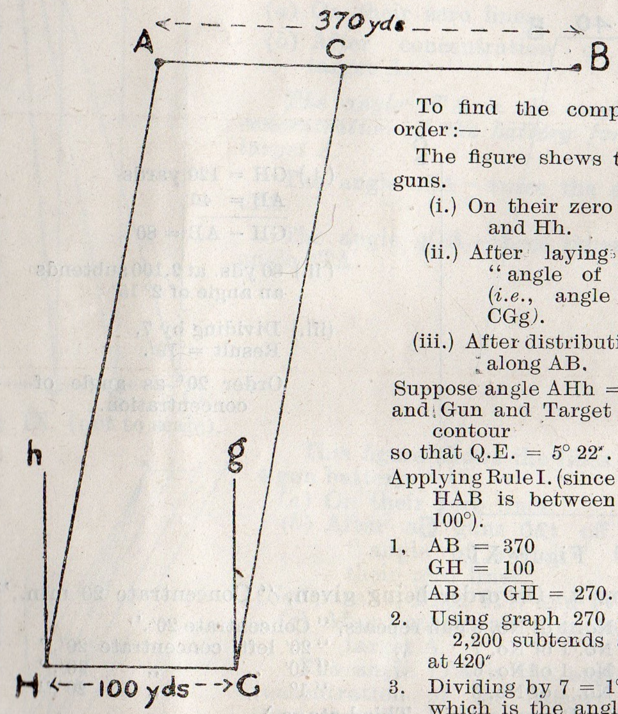
etc. (*See* Barrage Drill, Third stage.)

NOTE 2.—It will often be found that for flank barrages the working base, as found by the use of Rule II., will be less than the battery front, and it will then be necessary to use Rule III., and concentrate the fire.

NOTE 3.—*It will generally be sufficient, in order to engage a target such as an enemy concentration, to switch the fire of the battery on parallel lines without concentration or distribution of fire.*

Example:—Shewing distribution of fire along a target, after a switch.

A battery of eight guns on a frontage of 100 yards is ordered to engage a target 370 yards long at 2,200 yards range.



To find the complete fire order:—

The figure shews the flank guns.

(i.) On their zero lines Gg and Hh.

(ii.) After laying off the "angle of switch" (*i.e.*, angle AHh = CGg).

(iii.) After distribution of fire along AB.

Suppose angle AHh = 5° and Gun and Target on same contour so that Q.E. = 5° 22′.

Applying Rule I. (since the angle HAB is between 80° and 100°).

1. AB = 370
   GH = 100
   AB − GH = 270.
2. Using graph 270 yards at 2,200 subtends an angle at 420″
3. Dividing by 7 = 1° which is the angle of distribution.

The complete orders by the Battery Commander would be:—

Stand to.
All guns on zero.

All guns 5 deg. right.
No. 8 gun directs.
Distribute 1 deg.
Load.
Elevation 5 deg. 22 min.
Medium rate (or whatever rate is ordered).
Fire.

If this target formed part of a previously arranged barrage, the Battery Commander would place the results of his calculations in the Battery Chart as follows (*see* Appendix VI., No. 2):—

No. of Barrage.	Angle of Switch.	Distribution angle.	Range.	V.I.	Q.E.
A.	5° R.	1°	2,200	0	5° 22′

A.	8	7	6	5	4	3	2	1
	5° R	6° R	7° R	8° R	9° R	10° R	11° R	12° R

The lower part of the Battery Chart shows the *angle of deviation* of each gun from its zero line. This is found by combining the angle of switch with the distribution angle or the necessary multiple of the distribution angle.

It will be noticed that the angle of deviation of the directing gun equals the angle of switch.

From this part of the table the gun charts are compiled.

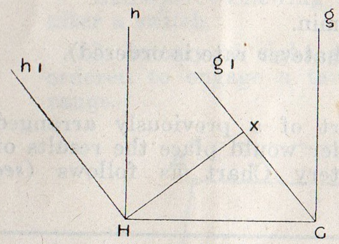
NOTE.—(i.) Where the situation does not permit the passing of orders, the Battery Commander will employ the most suitable means of conveying the fire orders to his guns, *e.g.*, by giving orders himself to each gun Commander in turn, or sending the orders by runner to the gun Commanders.

NOTE.—Appendix VI., No. 2 and No. 3, should be read before proceeding to Section 10, para. 4.

Frontage of battery.

Definition.

The frontage of a battery is the perpendicular distance between the parallel lines of the flank guns.



The figure shows:—

1. Zero lines of flank guns of a battery, Hh and Gg. As the angle hHG = 90 deg., the frontage of the battery = GH.
2. Parallel lines Hh_1 and Gg_1 after a switch.

The frontage of the battery is now HX, *not* GH.

Figure XII.

This is only equal to the distance between the guns when the angle (hHG) between the line of fire of the directing gun and the line of guns is a right angle.

The error arising from considering the battery frontage as the distance between the guns may be always neglected where the angle hHG is between 110 deg. and 70 deg.

In other cases greater accuracy will be ensured if the frontage HX is used rather than the distance between the guns GH.

To obtain HX:—

(*a*) Measure it on the map,

or (*b*) Use graph No. 2, Appendix V. (*See* above, Case II., Oblique Barrage.)

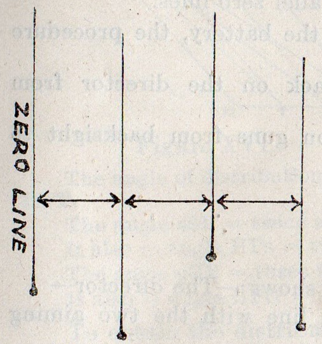
4. TO OBTAIN PARALLEL LINES OF FIRE.

(*a*) *It is very important that the lines of fire of the guns of a battery should be parallel when first laid out, and every effort should be made to attain this object.* The battery commander will then have a definite condition from which to make his calculations, and can switch his guns from one target to another without losing parallelism, distribute his fire correctly over a given front, or concentrate it on a given point, by means of the methods given above in para. 2 and para. 3. Any of the methods given below may be used, and the battery commander will choose that most suited to the situation. In general, the method depending on the distant R.O. is the quickest and most accurate, the compass the slowest and most inaccurate.

(*b*) *Methods depending on use of compass.*

Each gun is laid on the same bearing by compass. This bearing is the bearing of the zero line. The methods can be any of those given in Sec. 9.

The lines of a battery may be laid by compass when the ground renders it impossible to place the guns approximately in a line and there is no R.O. at a great distance.



The figure shows a four-gun battery in shell holes with parallel zero lines of fire.

Figure XIII.

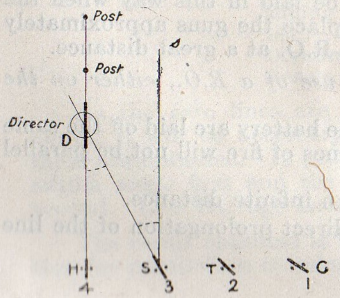
This may occur after the forward move of batteries to new shell hole positions, from which to create a S.O.S. barrage line. When firing in this direction the gun intervals should be as nearly equal as possible.

(*c*) *Methods depending on the use of a director or a gun used as a director.*

The zero line of the directing gun is laid out by any of the methods described in Sec. 9 and is marked by two posts.

The director is now placed in line with the two aiming posts at least 50 yards in front or rear of the battery, with the foresight towards the target and clamped at zero.

If a gun is being used the reading on the traversing dial is noted



The figure shows: — The director—

(i.) In line with the two aiming posts;

(ii.) Laid back on No. 4 gun;

(iii.) Laid back on No. 3 gun;

(iv.) No. 3 gun lays off the angle sSD = angle HDS, and is now on its zero line.

Figure XIV.

All guns now lay on the director.

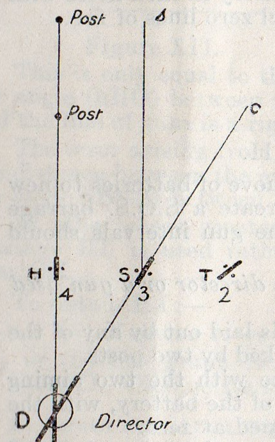
The controlling officer now faces the battery and lays back over the director (*foresight* over *backsight*) on to each gun in turn.

The angles swung through are noted and given to the guns. Each gun lays off the angle given to it, and an aiming post is put out. The guns are now in parallel zero lines.

Where the director is behind the battery, the procedure is the same, except:—

(i.) Guns are laid back on the director from *foresight* to *backsight*.

(ii.) Director is laid on guns from backsight to foresight.



The figure shows:—The director—

(i.) In line with the two aiming posts;

(ii.) Laid forward on No. 3 gun;

(iii.) No. 3 gun laid back on the director;

(iv.) No. 3 gun lays off the angle sSC = angle HDS, and is now on its zero line.

Figure XV.

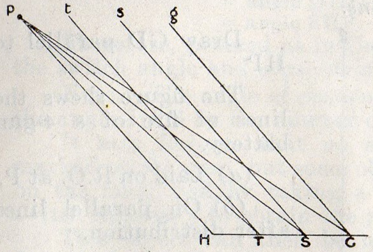
The lines of a battery may be laid in this way when the ground renders it impossible to place the guns approximately in a straight line and there is no R.O. at a great distance.

(*d*) *Methods depending on the use of a R.O., either on the map or put out.*

When all the guns of the same battery are laid off the same angle from the same R.O., the lines of fire will not be parallel unless:—

(i.) The R.O. is at an infinite distance.

(ii.) The R.O. is in direct prolongation of the line of the guns.



The figure shews the guns of a 4-gun battery:—

(*a*) Laid on the R.O. at P.

(*b*) After distribution to obtain parallelism.

Figure XVI.

The angle of distribution for the battery = angle tTP = angle HPT.

The angle sSP = twice angle tTP.

It also = angle HPs = twice angle HPT.

The angle gGP = three times angle tTP.

It also = angle HPG = three times angle HPT.

To obtain the distribution angle, measure the angle HPG and divide it by the number of gun intervals.

This is done by ordering flank guns to lay on each other and on R.O.; each gun notes the angle swung through. This measures angle PHG and PGH.

Add these angles together and subtract their sum from 180 deg. The result is angle HPG. Divide this angle by the number of gun intervals and this is the angle of distribution to obtain parallelism.

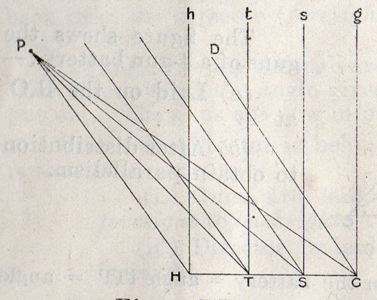
NOTE.—The three angles of a triangle added together 180 deg.

Example.—Angle PHG = 120°
Angle PGH = 57°
adding = 177°
180° − 177° = 3°
Dividing by number of gun intervals (3)
Result = 1°.

As the zero lines are unlikely to be the lines obtained above, it will be necessary to switch the parallel lines once these are obtained. In practice it is found better to order the switch angle first and the distribution angle for parallelism second. (*See* Barrage Drill, Stage 2.)

The result obtained is the same and the angle of distribution for parallelism is independent of the switch angle.

Case I.—R.O. in front of guns.



Draw GD parallel to HP.

The figure shews the lines of fire of a 4-gun battery.

(*a*) Laid on R.O. at P.

(*b*) On parallel lines after distribution.

(*c*) On parallel zero lines.

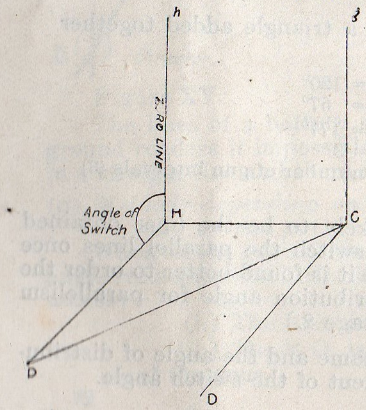
Figure XVII.

Then in order for the gun at G to fire on its zero line Gg, it must lay off the angle gGP = angle gGD plus angle DGP
= angle hHP plus angle HPG
= switch angle plus angle HPG.

Therefore, measure angle HPG as described above and divide this angle by the number of gun intervals. This is the angle of distribution for the battery.

Example:—If switch angle = 60°,
Angle of distribution = 1°.
Order—All guns on R.O.
All guns 60° right,
No. 4 gun directs,
Distribute 1°.

Case II.—R.O. behind guns.



The figure shows the flank guns of a battery:—

(*a*) Laid on R.O.;

(*b*) On parallel zero lines.

Draw GD parallel to HP. Since Hh and Gg are parallel, and HP and GD are parallel, therefore angle hHP = angle gGD, and angle HPG = angle PGD.

Figure XVIII.

Now the gun at G lays off the angle gGP
= angle gGD − angle PGD
= angle hHP − angle HPG.

Therefore, proceed as in Case I., order all guns to lay off the switch angle and *concentrate* instead of distribute.

NOTE.—The angle of concentration is obtained by dividing the angle HPG by the number of gun intervals.

It may happen that no suitable R.O. exists which is marked on the map, but some object may be used which is not on the map, and by taking a bearing to this the angle of switch necessary to obtain the zero line can be obtained.

This object can then be used to obtain parallelism as described above.

The R.O. must be as far away as possible, and it is sufficient if the guns are approximately in line.

If there is no suitable R.O. one must be put out in the line of the guns at a distance of at least 400 yards if possible; and the guns should be in line as accurately as possible.

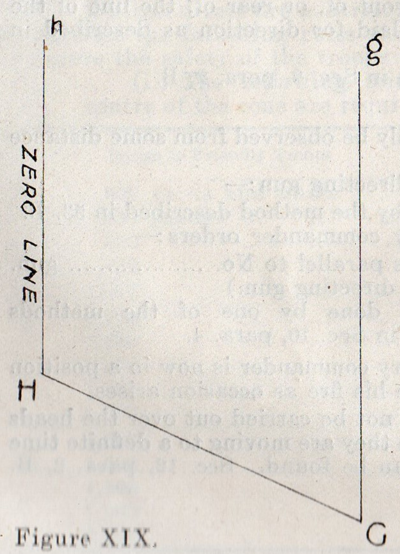
Here the bearing to the R.O. is taken from position of the directing gun.

It may happen that the R.O. is invisible from one of the gun positions or that the gun is out of line.

In this case its line can be laid:—

(*a*) By compass;

(*b*) By laying on any gun which has obtained its zero line.



The figure shews Hh the zero line of a gun already obtained, Gg the zero line of a gun obtained as follows:—

The guns lay on each other.

The gun at H records the angle hHG.

The gun at G subtracts this from 180 deg., and lays off the result from the gun at H. It is now on the parallel line Gg.

Figure XIX.

NOTE.—Since Hh and Gg are parallel, angle hHG plus angle gGH =180 deg.

5. INDIRECT FIRE BY MACHINE GUN BATTERIES WHERE A 1/20,000 OR LARGER SCALE MAP IS NOT AVAILABLE.

In order to deal with the tactical situation discussed in Section 40, Part I. (Open Warfare), provision must be made in the training of Machine Gun Units for applying the indirect fire of batteries without the use of contoured maps.

The principles of distribution and concentration of fire from parallel lines and the methods of obtaining parallel lines remain unchanged, but modifications are required in the method of laying out the zero line of the directing gun and obtaining its elevation.

In the following the word "director" will be taken to mean either a "director" proper or some means of improvising a director, *e.g.*, a machine gun, a compass in conjunction with an angle of sight instrument, or a sextant.

Two cases now arise:—

Case I.

Where the target can be seen from the vicinity of the battery position.

The line to the target is marked by two aiming posts.

The director is then placed in line with the two aiming posts at least 50 yards in front of, or rear of, the line of the battery, and the guns are laid for direction as described in Sec. 10, 4, c.

Elevation is obtained as in Sec. 9, para. 2, B.

Case II.

Where the target can only be observed from some distance to a flank.

The line of fire of the directing gun:—

(i.) Is laid out by the method described in 53, B.

(ii.) The battery commander orders:—

All guns parallel to No. .... gun.
(This being directing gun.)

This is done by one of the methods described in Sec. 10, para. 4.

In either case the battery commander is now in a position to distribute or concentrate his fire as occasion arises.

This type of fire should not be carried out over the heads of troops in the open, unless they are moving to a definite time table, and the clearances can be found. Sec. 12, para. 2, B.

11.—MAINTAINING LAYING.

After a gun has been laid for direction and elevation by any of the means described in Secs. 9 and 10, an aiming post is put out in order to maintain direction and elevation. The tangent sight slide is run up until the sights are aligned on the bull on the aiming post, and the laying is maintained by relaying on the bull between bursts. In addition, the elevation should be frequently checked by the clinometer. Appendix X. describes two types of aiming posts in use.

Inaccurate laying on the auxiliary aiming mark can only be avoided by training the personnel. Too much stress cannot be laid on this part of the machine gunner's training, as failure to realise the importance of accurate aiming may lead to fire becoming dangerous to our own troops, and a consequent loss of confidence by the infantry.

Machine gunners should be tested in aiming from time to time by the "triangle of error" method.

NOTE.—Where no form of artificial aiming mark is available, some natural object on the ground may be selected. This should only be regarded as a makeshift, and not taught as a general practice.

12.—SAFETY CLEARANCES.

The clearance at any point over which fire is being directed is the vertical distance of the centre of the cone above that point.

1. When indirect fire is carried out over the heads of our own troops the following rules must be adhered to in order to ensure the safety of the troops:—

(i.) The following minimum clearances of the centre of the cone are required:—

Range to Friendly Troops	Minimum Clearance	
	Yards	Metres
600 yards and under ...	11	10
700 yards	13	12
800	15	14
900	17	16
1,000	20	18
1,100	23	21
1,200	27	25
1,300	31	28
1,400	35	32
1,500	40	37
1,600	46	42
1,700	53	48
1,800	60	55
1,900	69	63
2,000	80	73

(ii.) Our own troops must not be more than 2,000 yards from the guns.

(iii.) Steps must be taken to prevent such extremes of traversing and searching as would violate (i.). This is best done by using traversing and elevating stops.

(iv.) Calculations must be carefully checked and atmospheric conditions allowed for.

(v.) The rigidity of the firing platform is essential. This is obtained by the use of the " T " base.

(vi.) Elevation must be frequently checked by the clinometer.

(vii.) The personnel must be highly trained in accurate aiming and relaying.

(viii.) The maps used must be accurate and the scale not smaller than 1/20,000.

(ix.) Worn barrels and tripods should not be used

(x.) Our own troops should be warned when firing is going to take place.

(xi.) Clinometers should be frequently tested.

The following table shows the various causes which may result in fire becoming dangerous, and how these causes may be avoided:—

Cause	How avoided
(i.) Worn barrels.	Replacement by new barrels, but the life of a barrel is increased by care in oiling and pulling through.
(ii.) Worn mountings.	Replacement by new tripods or by the use of washers.
(iii.) Bad holding.	Training of personnel.
(iv.) Bad laying on auxiliary aiming mark.	Training of personnel.
(v.) Extremes of traversing and searching.	Training of personnel and use of traversing and depression stops.
(vi.) Error in calculation.	Practice in the use of the Tables and Graph.
(vii.) Failure to allow for atmospheric conditions.	
(viii.) Inaccurate Clinometer.	Constant testing.
(ix.) Mounting sinking.	Use of " T " bases and care in construction of firing platforms.

The importance of the rigid platform may be better realised if it is remembered that a change of elevation of 30 min. is caused if the front legs sink 1/3rd inch while the rear legs remain fixed, and *vice versa* if the rear legs sink while the front legs remain fixed. As this error is neutralized by relaying on an auxiliary aiming mark, the necessity for constant and accurate relaying is again emphasized.

NOTE.—The safety clearances are based on:—

(i.) A possibility of 5 per cent. error in range on the map.

(ii.) A possibility of 10 per cent. error in range, due to worn barrel, bad holding, etc.

(iii.) A possible error of 40 min. in the play of the tripod.

(iv.) Allowance for the lowest shot of the cone.

2. (A) To find the clearance over the friendly troops, using Tables 2 (A) or 2 (B) (Appendix IV.).

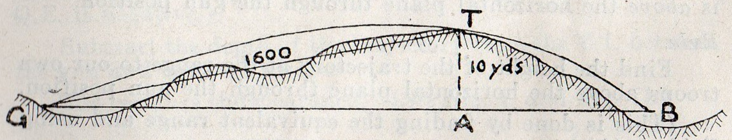
Definition of equivalent range.

The range at which the centre of the cone would strike the horizontal plane through the gun position.

It is found by using Table 1, Columns 1 and 2, and is used to determine the heights of the trajectories above the horizontal plane by means of Table 2 (A).

NOTE.—There is no equivalent range if the Q.E. is negative.

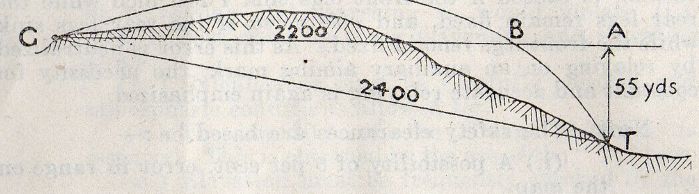
Example 1. Target above gun.



The figure shows the trajectory to hit the target at T and GB, the equivalent range on the horizontal plane through the gun position.

If GT = 1,600 yards
and target is 10 yards *above* gun.
Table 3 (A) gives QE = 177′.
Table 1, Columns 1 and 2 shew equivalent range = 1,700
i.e., GB = 1,700.

Example 2.



Target below gun.

The figure shows the trajectory to hit the target at T and GB, the equivalent range on the horizontal plane through the gun position.

If GT = 2400 yards
and target is 55 yards *below* gun
Table 3 (B) gives Q.E. = 322′
Table 1, Columns 1 and 2 shew equivalent range = 2200
i.e., GB = 2200.

Procedure to find clearance.

Determine Q.E. and, when possible, the equivalent range.
Note the gun contour.
Note the friendly troops contour.
And so obtain the V.I. between the gun and our own troops.

The following two cases may arise:—

Case I.

Where the trajectory, as it passes over our own troops, is *above* the horizontal plane through the gun position.

Rule.

Find the height of the trajectory at the range to our own troops above the horizontal plane through the gun position.

(This is done by finding the equivalent range and using Table 2 (A).)

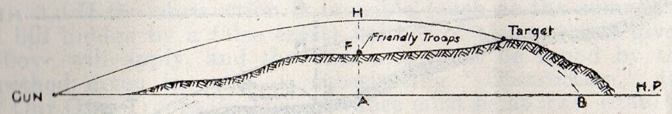
If the friendly troops are above the gun, *subtract* the V.I. between the gun and our own troops from the trajectory height.

The result is the clearance. (*See* Fig. I.)

If our own troops are below the gun, *add* the V.I. to the trajectory height.

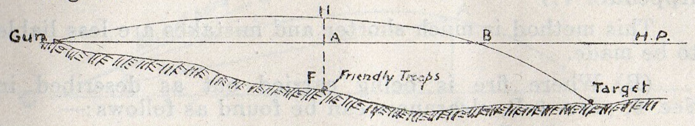
The result is the clearance. (*See* Fig. II.)

Fig. I.



HA = height of trajectory above HP.
FA = V.I. between our own troops and gun.
Clearance = HA − FA.
= HA − VI.

Fig. II.



HA = height of trajectory above HP.
FA = V.I. between our own troops and gun.
Clearance = HA + FA.
= HA + VI.

Case II.

Where the trajectory as it passes over our own troops is *below* the horizontal plane through the gun position.

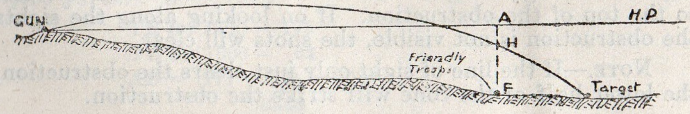
Rule.

Find the depth of the trajectory at the range to our own troops below the horizontal plane through the gun position.

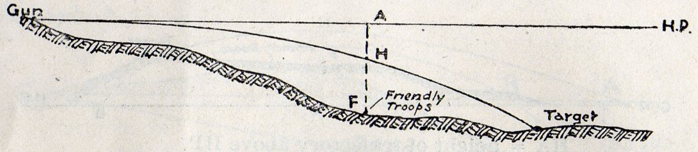
(This is done by finding the equivalent range and using Table 2 (A) if the Q.E. is positive, by using Table 2 (B) if the Q.E. is negative.)

Subtract the depth of the trajectory from the V.I. between the gun and our own troops.

The result is the clearance. (*See* Fig. I. and Fig. II.)



HA = Depth of trajectory below HP.
FA = V.I. between our own troops and guns.
Clearance = V.I. − HA.



HA = Depth of trajectory below HP.
FA = V.I. between our own troops and guns.
Clearance = V.I. − HA.

Clearances may also be found by using graph No. 1. *(See Appendix V.)*

This method is much shorter and mistakes are less liable to be made.

(B) Where fire is being carried out as described in Sec. 9, para. 2 B, clearances can be found as follows:—

(i.) Determine the range to our own troops and the angle of sight from the gun to our own troops in exactly the same manner as determining the range to the target and the angle of sight to the target.

(ii.) Obtain the V.I. between the gun and our own troops from the formula:—

$$\text{V.I.} = \frac{(\text{Angle of sight from gun to our own troops}) \times (\text{Range from gun to our own troops})}{3{,}400}.$$

It is now simple to find the clearance proceeding, as described in 2 (A) above.

3. CLEARING THE OBSTRUCTION.

In all cases where an obstruction exists between the gun and the target, it is necessary to ensure that the shots will clear the obstruction before opening fire.

To do this:—

1. After the gun has been laid for direction and elevation adjust the tangent sight slide to read the range from the gun to the top of the obstruction. If on looking along the sights the obstruction is not visible, the shots will clear.

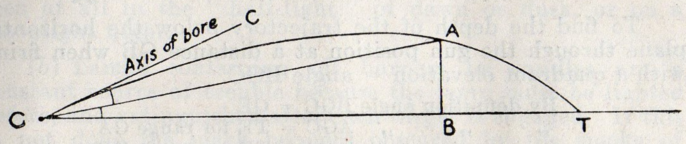
NOTE.—If the line of sight only just clears the obstruction, the lower half of the cone will strike the obstruction.

2. If the distance to the obstruction is under 100 yards put the sights at zero (the gun being already laid for direction and elevation); if, on looking along the sights the obstruction is not visible, the shots will clear.

3. If the obstruction is invisible (such as the summit of a hill hidden by a false crest) neither of the methods given above will apply, and the clearance must be found by the method given in para. 1, substituting "Obstruction" for "Our Own Troops." The clearance must be at least equal to half the height of the cone.

*4. TRAJECTORY TABLES.

Table 2 (A) is the trajectory table for positive quadrant elevations. It is compiled as follows:—



To find the height of the trajectory at a distance GB when firing at a range GT.

By definition angle TGC = TE for range GT, Sec. 49, para. 1, and assuming the rigidity of the trajectory,

By definition angle AGC = TE for range GA
= TE for range GB

(since GA = GB approximately the angle AGB being small).

But angle BGA = angle TGC − angle AGC
= TE for range GT − TE for range GB.

Now applying the angle of sight formula

$$S = \frac{VI}{HE} \times 3348 \text{ and so } VI = \frac{S \times HE}{3438}$$

and remembering S = angle BGA. Sec. 49, para. 3.

VI = AB
HE = GB

$$\text{the clearance AB} = \frac{(\text{TE for range GT} - \text{TE for range GB}) \times \text{GB}}{3438}$$

Example:—To find height of 1,700 yards trajectory at 1,000 yards.

TE for 1700 = 177
TE for 1000 = 62

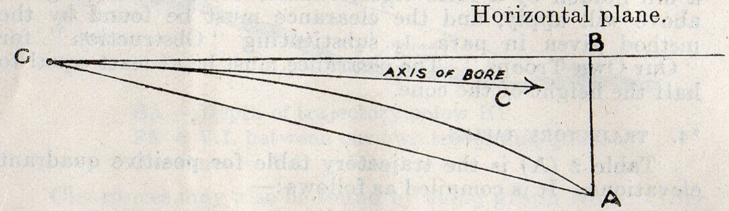
$$AB = \frac{(177 - 62) \times 1000}{3438}$$

$$= \frac{115 \times 1000}{3438}$$

$= 33{\cdot}4$ yards.

Table 2 (A) gives 33·3.

Table 2 (B) is the trajectory table for negative quadrant elevations. It is compiled as follows:—



To find the depth of the trajectory below the horizontal plane through the gun position at a distance GB when firing with a quadrant elevation = angle BGC.

By definition angle BGC = QE
,, ,, ,, AGC = TE for range GA
= TE for range GB
(since GA = GB approximately)
But angle BGA = angle BGC + angle AGC
Now applying the angle of slight formula

$$S = \frac{\text{V.I.}}{\text{H.E.}} \times 3438$$

and remembering S = angle BGA
V.I. = AB
H.E. = GB

$$\text{Then AB} = \frac{(\text{QE} + \text{TE for range GB}) \times \text{GB}}{3438}$$

Example:—Supposing a negative angle of Q.E. of 100 min.

To find depth of trajectory below horizontal plane at a distance of 1,000 yards.

Then TE for 1000 yards = 62′.

$$\text{AB} = \frac{(100' - 62') \times 1000}{3438}$$

= 47·1 yards.
Table 23 (B) gives 47·2.

In addition, all graphs and other aids to determine clearances without calculation are based on these Trajectory Tables.

13.—NIGHT FIRING.

1. When indirect fire is carried out by night, the gun position must be fixed by day, and a post at some known direction from the gun position must be placed in the ground

by day, or at dawn or dusk, as it is usually impossible to do these things with accuracy after dark. After dark, the post must be replaced by some illuminated aiming mark.

2. *Night Aiming Mark.*—(*a*) Experiments with aiming marks covered with luminous paint have not proved successful. Even on a dark night such aiming marks require very frequent exposure to artificial light in order to retain the necessary luminosity, and even then afford no *definite* point of aim.

Another objection is that such aiming marks cannot be seen at all in the "half-light" of dawn or dusk, or on a moonlight night.

(*b*) Lamps containing oil burners or candles are a constant source of trouble because the lamp must be lighted before, and extinguished after each target is engaged. If this is not done the mark becomes obscured by the smoke of combustion, and in the case of a candle the lamp becomes hot and the candle melts.

(*c*) The most satisfactory aiming mark is an electric box as described in Appendix X.

The light can be switched on from the gun position and can be put out as soon as the firing is completed. The box is easily carried and is not likely to break during transport.

The aiming mark is 12 inches wide, and therefore, when placed 9½ yards from the gun, gives a traverse of 2 degrees. This is a great advantage over "point" aiming marks, where the limit of traverse has to be guessed.

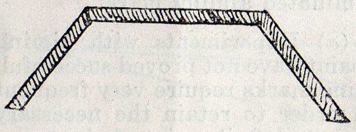
With this aiming box, used in conjunction with the luminous bar foresight (Appendix X.) and a luminous backsight, any type of indirect fire, including barrage fire, can be performed by night with accuracy.

3. *An Electric Torch* is essential at the gun for reading graduations on the Direction Dial and tangent sight, and for setting the clinometer.

4. *Depression Stops* and *Traversing Stops*, when set correctly, automatically ensure the safety of our own Infantry, and thus diminish the strain on the firer.

5. *Flash Obscurers* have been produced which effectively conceal the flash from view, but they invariably disperse the cone to such an extent that they make overhead fire impossible. Consequently, there is no pattern which can be recommended.

On the other hand, it has been proved experimentally that screens of canvas or sandbags have no effect on a cone which is fired through them, and such screens when wet effectively screen the flash. Care should be taken to screen the flash at the sides as well as the front.



6. When the firing is done from positions some way behind our front line, and especially when this is reached by overland routes, special precautions must be taken against endangering friendly troops who are passing near the gun position.

This is done by posting sentries or by wiring in the danger area. The safety of working parties and patrols in No Man's Land must be secured by liaison with Battalions.

14.—SEARCHING REVERSE SLOPES.

In order to search a reverse slope effectively, the gun must be placed at such a distance from the crest that the fall of the bullet is steeper than the slope of the ground.

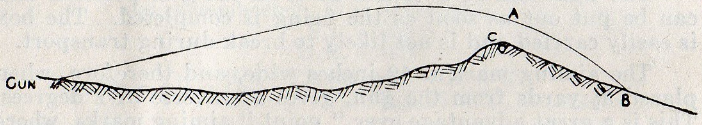


Table 7 (Appendix IV.) has been compiled to enable the machine gunner to do this without making elaborate calculations. If this Table be used according to the following instructions, the angle ABC (*see* diagram above) will be between 100 and 200 minutes.

1. METHOD OF USING TABLE 7.

(i.) Find the fall in yards, per 100 yards of the slope. To do this it is best to find the fall for several hundred yards of the slope, and then calculate the average fall per hundred yards.

(Suppose the fall is 6 yards per 100 yards.)

(ii.) Draw a line on the map representing the probable line of fire. This will be so as to engage the target in enfilade when possible.

(iii.) Observe from the map, whether the gun is likely to be above or below the top of the slope.

(iv.) Suppose it is above. On the right half of Table 7 (Gun above Crest) and in the top column find the figure 6, and notice the range in the column beneath it (*i.e.*, 1,400 yards).

(v.) Measure back from the top of the slope 1,400 yards along the line of fire.

(vi.) Find the difference between the height of this point and the height of the top of the slope (say 20 yards).

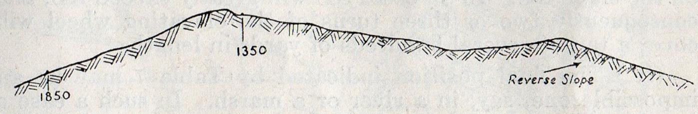
(vii.) Find 20 in the centre column, and, reading along the column to the right, find the range below the 6 in the top column (*i.e.*, 1,600 yards).

(viii.) Measure back 1,600 yards from the top of the slope, along the line of fire. The point thus found is the point in which to place the gun.

(ix.) Knowing the gun position, and the position and height of the top of the slope, find by the ordinary methods of indirect fire, the direction and elevation necessary to hit the top of the slope.

2. SPECIAL POINTS.

(i.) In certain cases both sides of Table 7 may be satisfied.



Example:—

Fall 5 yards per 100 yards.

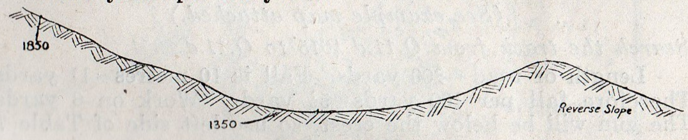
Then using the right side of Table 7, the gun must be placed 1,350 yards from the slope, when the gun is above the crest. Or, using left side, if the range is 1,850 yards, the gun must be below the crest.

In such a case the controller can decide for himself which position is the best to occupy.

(ii.) Neither side of Table 7 may be satisfied.

Example:—

Fall 5 yards per 100 yards.

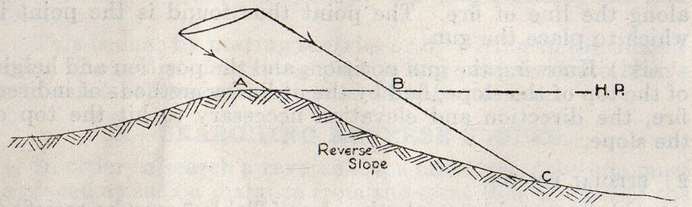


Sec. 14.

On measuring back 1,350 yards, the gun may be *below* the crest, and in measuring back 1,850 yards, the gun may be *above* the crest. In such a case, which will be extremely rare, choose a position between the two which is on the same level as the crest. The reverse slope can be engaged from this position.

(iii.) As the searching of reverse slopes is just a special type of indirect fire, searching and traversing will be employed as usual, with the exception that searching will be very restrained.

If AB represents the length of the beaten zone on the horizontal plane, AC will represent the length of beaten zone



on the slope AC. In all cases AC will greatly exceed AB, and consequently two or three turns of the elevating wheel will cover a target several hundreds of yards in length.

(iv.) The final position indicated by Table 7 may be an impossible one, say, in a river or a marsh. In such a case a gun position should be selected further away from the slope rather than nearer to the slope.

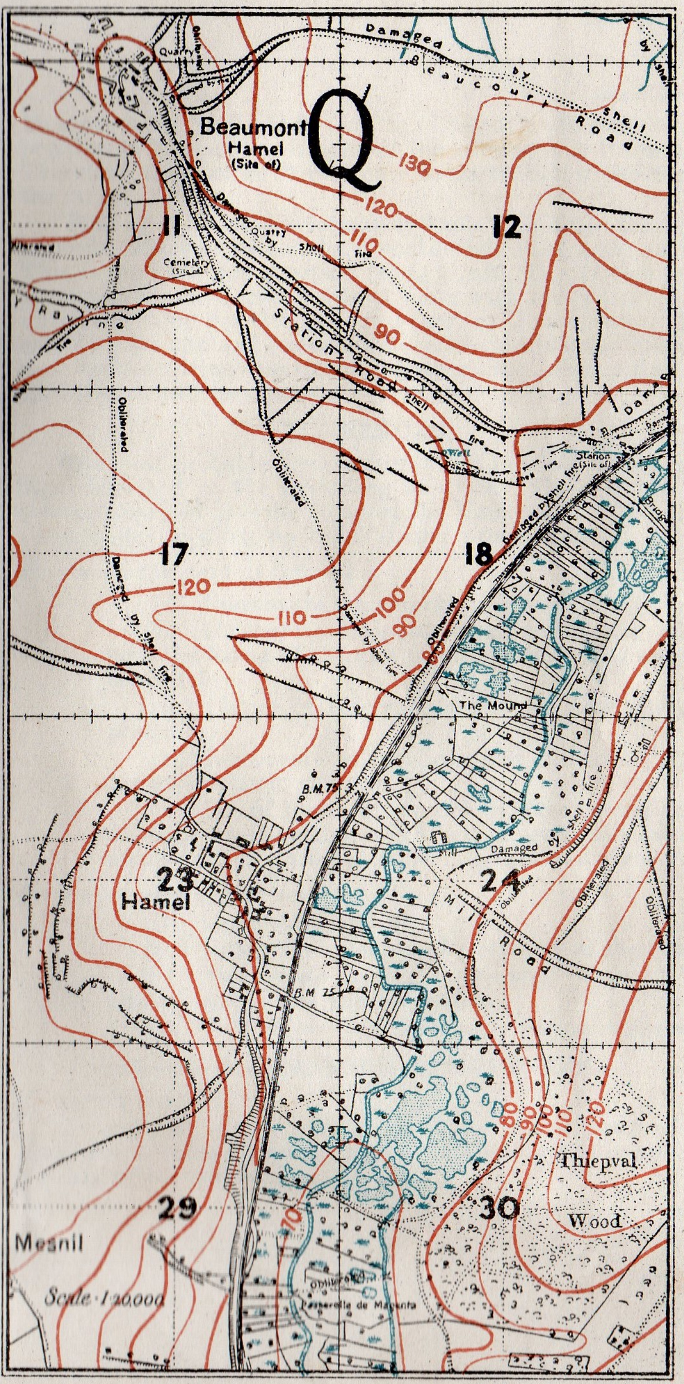
By moving further back the range is increased, and consequently the angle of descent of the bullet, but by going nearer to the crest the angle of descent is decreased, and it may become impossible to search the reverse slope at all.

(v.) Fire should be directed at the top of the target, which may, or may not, be the crest of the hill. If the top of the target is not the top of the hill, calculations should be made to see if the hill will be cleared or not. If the crest is not cleared, the gun should be taken back to such a range that the obstruction will be cleared.

(*See example map attached.*)

Search the track from Q.11.d.4615 to Q.11.d.3951.

Length of road = 200 yards. Fall is 10 metres = 11 yards. Therefore fall per 100 yards = $5\frac{1}{2}$ yards. Work on 6 yards. The gun will be below the crest, so use left side of Table 7.



To face page 88.

Measure back 1,850 yards (*i.e.*, Q.24.c.22.51). Height of this position is 71 metres. Height of top of target is 110 metres. Therefore the gun is 39 metres = 43 yards below the top of the target.

Find 40 in the centre column of Table 7, and find the range opposite this and below the 6 on the left (*i.e.*, 1,800 yards). This is the final gun position (at Q.24.c.20.57). If this point is unsuitable for a gun position, move back along line of fire until a suitable position is found (say, at Q.24.c.3100). Then calculate the angle of quadrant elevation in the usual manner, and before firing ascertain whether the obstruction at Q.17.b.60.30 will be cleared.

15.—ERRORS.

The most probable errors which affect indirect laying have been described in the preceding analysis. These errors are now summarised in order to assist the Machine Gun Company Commander to draw up his training programme.

Errors on the part of Officers.

(i.) Inaccurate map work.

(ii.) Inaccurate compass work, which may affect both the fixing of the gun position and laying out the line of fire.

(iii.) Choice of reference object too near the gun position.

(iv.) Inaccurate calculations and failure to allow for atmospheric changes.

(v.) Use of instruments such as clinometers, angle of sight instruments, when not in accurate adjustment, and of worn-out material, such as barrels, etc.

Errors on part of Personnel.

(i.) Inaccurate aiming.

(ii.) Inaccurate placing of elevation on the gun.

(iii.) Inaccurate use of traversing dials, "T" aiming marks and bar foresights.

(iv.) Failure to "oil up," etc., during a barrage.

16.—MODIFICATIONS IN EQUIPMENT.

1. SAFETY DEVICES.

In order to secure the safety of the troops, over whose heads fire is being directed, it is most important to ensure the rigidity of the mounting.

Without this, traversing and depression stops do not prevent fire becoming dangerous if the mounting sinks, because these form parts of the mountings. This rigidity is obtained:—

(i.) By careful construction of firing platforms.

(ii.) By the use of "T" bases.

The latter is much preferable.

Fig. 1, Appendix IX., shows a type of "T" base easily made, but which must be adjusted to each tripod.

Fig. 2, Appendix IX., shows a type which is:—

(i.) Collapsible and therefore more easily carried, and less likely to render the carrier conspicuous.

(ii.) Adjustable.

After the tripod has been placed on the "T" base, which in soft ground should be reinforced by a layer of sandbags underneath, a few sandbags are placed across the legs.

Provided that a rigid mounting has been obtained, traversing stops prevent the firer swinging his gun beyond the prescribed limits of traverse.

At the same time depression stops prevent the fire becoming dangerous by depression of the gun.

2. In order to obtain the accuracy of direction now required for indirect fire, it is necessary to be able to lay off to 10 min. This cannot be done by the direction dial, and is done by:—

(i.) The "T"-shaped aiming mark, Fig. I., Appendix X.: This is graduated in inches, and, when placed $9\frac{1}{2}$ yards from the gun—

1 inch represents a traverse of 10 minutes.
6 inches ,, ,, ,, ,, 1 degree.

The aiming mark gives a traverse of 3 degrees either side. It cannot be used at night.

(ii.) The combination of the bar foresight, telescopic aiming post and night-firing box, Fig. 2, Appendix X., allows:—

(*a*) 7 deg. either side of the centre to be laid off and readings to 10 min. intervals.

(*b*) A traverse of 2 deg. either side of the centre line by placing the post $9\frac{1}{2}$ yards from the gun, with arms horizontal.

(*c*) Elevation through 4 deg. if the arms are vertical.

(*c*) Elevation through 4 deg. if the arms are 1 deg. either side of centre without moving the cursor on the bar foresight, and 7 deg. to be laid off either side of the centre by moving the cursor.

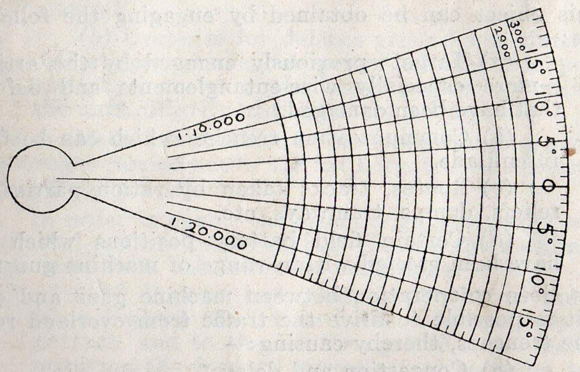
3. Bayonet signalling shutters (Venetian flappers) have been often used for controlling the fire of a battery.

4. Condenser bags have been found useless, and are replaced by petrol tins.

5. The introduction of a rotatable dial much simplifies laying off angles, as it overcomes the difficulties of addition and subtraction, over which mistakes have been easily made in the past.

6. The necessity of accurate indirect fire by a large number of guns renders necessary clinometers on a scale of one per gun.

7. Some form of large protractor in the shape of a sector of a circle with an angle of 30-45 deg.



17.—MACHINE GUN BARRAGE FIRE.

(*See Part I., Sec. 5 and 6.*)

1. Barrage fire by machine guns is the fire of a large number of guns acting under a centralised control, directed on to definite lines or areas, in which the frontage engaged by a gun approximates 40 yards.

Barrage fire is carried out by:—

(i.) Artillery.
(ii.) Trench Mortars.
(iii.) Machine Guns.

The best results in any operation can only be obtained by conceiving the barrage plan as a whole and allotting to the different weapons tasks which their characteristics render them most fitted to carry out.

There are four types of barrage fire:—

(i.) Preliminary bombardment.
(ii.) Creeping barrage.
(iii.) Standing barrage.
(iv.) Back area barrage.

2. The "harassing fire" of machine guns forms an integral part of the preliminary bombardment, and the object of the fire is to:—

(i.) Lower efficiency of enemy working parties
(ii.) Increase difficulty of transport of munitions and supplies.
(iii.) Cause deterioration of enemy morale.

This object can be obtained by engaging the following targets:—

(*a*) Targets previously engaged by the artillery —more especially wire-entanglements and defences that have been damaged.

(*b*) Communication trenches which can be taken in enfilade.

(*c*) Routes, tracks taken by ration parties and reliefs, dumps, tramways, etc.

(*d*) Certain field battery positions which may have been erected within range of machine gun fire.

By close co-operation between machine guns and other arms it is possible to drive the traffic from overland routes into the trenches, thereby causing:—

(*a*) Congestion and delay.

(*b*) Casualties from the artillery fire on the communication trenches from their enfilade guns.

During the period more closely approaching zero day when the enemy defences have been knocked about and the morale of the garrison has been shaken, the plan of concentrating the guns of one battery on to carefully chosen centres

of activity, and opening rapid fire for a short period is effective. This type of fire is known as "area shooting." This treatment should be applied to different points at irregular intervals.

3. The objects of barrage fire on zero day are to:—

(*a*) Prevent the enemy manning his parapets and installing his machine guns.

(*b*) Interfere with the effective use of machine guns in rear.

(*c*) Prevent supplies of food and ammunition being brought up.

(*d*) Prevent reinforcement of the garrison.

(*e*) Destroy morale.

(*f*) Place a protective barrage at every definite stage of an advance.

(*g*) Save our own troops at all times from casualties by keeping down the fire of the enemy infantry, machine guns, etc.

By these means Infantry Battalions are enabled to:—

(*a*) Advance and seize objectives previously allotted.

(*b*) Organize for defence ground won during the delicate period when troops are suffering from nervous and physical strain, the loss of leaders and men, and the unfamiliarity of their surroundings.

These objects are obtained by creeping, standing and back area barrages carried out by the artillery, trench mortars, and machine guns in conjunction.

4. In order to enable the machine guns to carry out the *rôle* allotted to them in the barrage scheme, the machine gun barrage must fulfil the following conditions:—

(i.) It must be equally applicable to the "set piece" where the "time factor" is relatively unimportant, and to the later stages of large operations involving the forward movement of batteries to new positions from which to create a barrage, in which case the "time factor" becomes of paramount importance.

(ii.) It must apply also to conditions of semi-open and open warfare, becoming relatively more important as the troops get out of range of the bulk of their artillery.

(iii.) It must be flexible, *i.e.*, it must be possible to create a zone of intense machine gun fire on any area with accuracy and rapidity.

(iv.) It must be capable of being taught and carried out as a drill.

These conditions can only be obtained by simplicity of:—

(*a*) Organization.
(*b*) Laying.
(*c*) Fire Control.
(*d*) Drill.

5. ORGANIZATION OF GUNS FOR BARRAGE FIRE.

(*a*) Guns for barrage fire are organized into groups and batteries. The group normally consists of between 16 and 24 guns. If the group is considerably larger, it will be necessary to divide it into sub-groups, each under a sub-group commander. The group is commanded by the Group Commander, who is a Company Commander, but may be the D.M.G.O.

His normal position is at the Brigade Headquarters in whose area he is operating. He is assisted by an officer. Normally each Brigade has one group of barrage guns.

The group is divided into batteries or fire units of 4, 6 or 8 guns. The normal size of a battery is 8 guns. Each battery is commanded by an officer who is known as the Battery Commander. He is assisted by one officer per four guns and one N.C.O. to every two guns—who is not below the rank of corporal. Each gun is commanded by a N.C.O. or senior private—who is *not* the No. 1 of the gun and is known as the Gun Commander.

Batteries are lettered from the right A, B, C, etc., throughout the Corps front; in the case of a forward move these become A2, B2, C2, etc., for the first move; A3, B3, C3, etc., for the second move, and so on.

(*b*) The duties of the Group Commander are:—

(i.) To carry out the orders of the D.M.G.O.

(ii.) Organize his group into batteries.

(iii.) To make all preliminary preparations, which include estimates of S.A.A., oil, water, etc.

(iv.) To make preparation for the formation of dumps and communications.

(v.) Issue operation orders which deal with the location and tasks of each battery. The task is in the form of a table showing the times, targets, rates of fire for each lift, and any moves. These orders must be issued in ample time for the Battery Commander to make his calculations and send these to the Group Commander to check.

(vi.) To provide himself with a fighting map showing zero lines and tasks of each battery (Appendix VII., No. 1).

(*c*) The duties of the Battery Commander are:—

(i.) To lay out the zero lines of his battery in the position ordered by the Group Commander.

(ii.) To carry out orders of the Group Commander detailed above in (iii.), (iv.), and (v.).

(Specimen of Battery Charts, Appendix VI.)

(iii.) To issue a gun chart to each Gun Commander. (Appendix VI., No. 3.)

(iv.) To provide himself with a fighting map showing zero lines and tasks of his battery. (Appendix VII., No. 2.)

(v.) To see that every "Commander" in his battery, including himself, is provided with an understudy.

(vi.) To supervise the fire of his battery.

(*d*) The duties of the Gun Commander are:—

(i.) To control the fire of his gun as ordered on his gun chart.

(ii.) To control the fire as taught in "Barrage Drill."

(iii.) To see the correct elevation and direction is *placed* and *maintained* on his gun.

(iv.) To watch for signals from the officer controlling the fire.

(v.) In the event of a barrage not on the chart being ordered, to see that the correct fire order is passed down, and that his gun is correctly laid before repeating "No. — gun, ready to fire."

These duties can only be performed *in toto* when the tactical situation permits. It will often be impossible to prepare elaborate fighting maps and charts.

6. LAYING AND FIRE CONTROL.

Although machine gun barrage fire can be carried out by controlling the fire of each gun singly, experience has shown that the barrage so produced is not flexible, that calculations are laborious, and control difficult.

The introduction of the Battery System (*see* Section 10) has rendered it possible to produce a flexible barrage, easily controlled and obtained by the aid of extremely simple calculations. This is the normal method of producing machine gun barrage fire.

7. BARRAGE DRILL.

In order that a battery may work in the field with efficiency, the methods of battery fire must be learnt as a drill. This will enable the personnel in action to reproduce automatically the movements learned in practice, with such modifications as the conditions of battle may impose.

Equipment Required.

Guns and tripods.
Spare parts.
Ammunition boxes (4 per gun).
Condenser tubes and bags (or petrol tins).
" T " shaped bases.
Zero aiming posts and " T " aiming marks.
Sandbags and shovels.
Shutter for controlling fire.
Clinometers or spirit levels.
Megaphone.

First Stage.

Guns and equipment will be laid out as in elementary drill. A Gun Commander will be appointed for each gun.

(i.) " FALL IN."—Teams fall in as in elementary drill, Gun Commanders on the right of No. 1. Teams in line, dressed by the right.

(ii.) Battery Commander indicates the reference object (if one is being employed).

(iii.) " NUMBER."—As in elementary drill.

(iv.) " TAKE POST."—As in elementary drill, all numbers standing to attention.

No. 3 has with him condenser bag (or petrol tin), four boxes of ammunition and aiming post.

No. 4 has " T " shaped base and shovel. Gun Commander takes up position on left of No. 1, with cleaning rod and clinometer.

(v.) " TELL OFF BY GUNS."—Gun Commanders number off from the right:—No. 1 gun, etc.

(vi.) " PREPARE FOR BARRAGE."—No. 1 examines the tripod and No. 2 prepares the gun (condenser tube fixed) for action.

No. 3 inspects the ammunition.

No. 4 doubles forward with " T " shaped base and shovel.

Battery Commander aligns " T " shaped bases, and on the Battery Commander's signal Nos. 4 fix the bases firmly in the ground, and double to the rear.

Nos. 5 and 6 fill sandbags and prepare for belt filling, under cover.

Second Stage.

To obtain parallel zero lines in the required direction, the following is only one of several methods taught. All methods should be practised.

(vii.) " FLANK GUNS—MOUNT GUN."—The flank guns mount on the " T " shaped bases, Nos. 4, 5 and 6 bringing up sandbags, guns lay on each other, No. 2 of each gun notes reading on direction dial and signals with his hand to the other No. 2, when this is complete. Both guns now lay on R.O. and note the angle swung through. These angles are passed along to the Battery Commander, who then calculates the distribution angle to obtain parallel lines.

(viii.) " REMAINDER — MOUNT GUN."—Remaining guns mount guns on " T "-shaped bases and lay on R.O.

No. 3 of each gun brings up four boxes of ammunition and condenser bag (or petrol tin).

Nos. 4, 5 and 6 bring up sandbags.

Nos. 2 and 3 sandbag the tripod.

No. 2 fixes condenser bag (or petrol tin).

Gun Commander takes up clinometer and cleaning rod.

(ix.) " ALL GUNS—DEGREES RIGHT OR LEFT."—(This angle will be such that it brings the zero lines of the directing gun in the required direction.)

This order is repeated by Nos. 1 in succession from the left, who immediately lay off the angle ordered.

Nos. 3 double forward to the gun, and pace out 9½ yards carrying zero posts and " T " shaped aiming marks. The " T " aiming mark is placed as ordered by No. 1, and is held in position by No. 3, pending the order of distribution to obtain parallel lines.

(x.) " No. —— GUN DIRECTS."—(Normally this will be left gun.) This order is repeated by each No. 1.

(xi.) " DISTRIBUTE 20 min."—This is the angle obtained by the battery commander in para. 7.

The angle 20 min. has been used simply for the purpose of illustration. The same applies to all subsequent angles.

Then for a battery of eight guns this order would be passed along as follows:—

No. 1 of No. 8 gun repeats " Distribute 20 min." No. 3 fixes zero post and " T " aiming mark as ordered by No. 1.

No. 1 of No. 7 gun repeats " 20 min. right—Distribute 20 min.," and lays off 20 min. right on " T " aiming mark. No. 3 then fixes zero post and " T " aiming mark as ordered by No. 1.

No. 1 of No. 6 gun repeats " 40 min. right—Distribute 20 min.," and lays off 40 min. right on " T " aiming mark. No. 3 then fixes zero post and " T " aiming mark as ordered by No. 1—and so on for the remaining guns.

The guns are now laid on their parallel zero lines.

Before proceeding with the drill the Battery Commander will order " Check zero lines," when the orders given in 9, 10 and 11 will be repeated, with the exception that the zero posts will be left in the ground.

These zero posts will not be moved once parallel lines have been obtained.

(xii.) " STAND CLEAR."—Teams fall in five yards in rear of gun and stand at ease.

Third Stage.—Distribution and Concentration.

(xiii.) " STAND TO."—Nos. 1 and 2 take up their positions at the gun. The Gun Commander kneels down with the clinometer on the left of No. 1.

(xiv.) EXAMPLES OF DISTRIBUTION.—" All guns 6 deg. right." Each No. 1 repeats and lays off 6 deg. right from zero, using direction dial.

" No. 8 Gun Directs." Each No. 1 repeats.

" Distribute 1 deg. 10 min." This order is carried out as explained in 11.

(xv.) EXAMPLE OF CONCENTRATION.—" All guns 5 deg. left." Each No. 1 repeats and lays off 5 deg. left from zero, using direction dial.

" No. 8 gun directs." Each No. 1 repeats.

" Concentrate 20 min." No. 1 of No. 8 gun repeats " Concentrate 20 min."

No. 3 fixes his " T " aiming mark.

No. 1 of No. 7 gun repeats " 20 min. left—Concentrate 20 min.," and lays off 20 min. left on the " T " aiming mark. No. 3 then fixes the " T " aiming mark as ordered by No. 1.

No. 1 of No. 6 gun repeats " 40 min. left—Concentrate 20 min.," and lays off 40 min. left on " T " aiming mark. No. 3 then fixes the " T " aiming mark as ordered by No. 1—and so on.

(xvi.) " LOAD."—As in elementary drill.

(xvii.) " ELEVATION 3 deg."—Each No. 1 repeats and Gun Commander lays the gun for elevation.

No. 1 adjusts the tangent sight on the " T " shaped aiming mark, and notes the reading.

(xviii.) EXAMPLE OF COMBINED SIGHTS.—" Elevation 4 deg. 20 min.—20 min. differences." No. 1 of No. 8 gun repeats " Elevation 4 deg. 20 min.—20 min. differences."

Gun Commander sets clinometer at 4 deg. 20 min.

No. 1 of No. 7 gun repeats " Elevation 4 deg. 40 min.—20 min. differences."

Gun Commander sets clinometer at 4 deg. 40 min.

(xix.) TRAVERSE will be 1 deg. right, 1 deg. left, unless otherwise ordered. No traverse for concentration.

(xx.) RATE OF FIRE—Slow, medium, or rapid.

(xxi.) " FIRE."—Shutter lowered.

Bursts of fire should not be less than 15-20 rounds.

No. 1 relays between bursts.

Unless concentrating tap between bursts.

Accuracy in relaying must always be insisted on.

(xxii.) " CEASE FIRE."—Shutter released.

Procedure after first lift or first belt. (Whichever is shorter.)

No. 1 unloads and clears gun.

No. 2 removes outer casing, tests muzzle cup and cleans the barrel, replaces outer casing.

No. 1 oils up, reloads and lays for direction.

Gun Commander puts on elevation.

No. 2 signals ready to fire.

Procedure after every 1,000 rounds:—

No. 1 unloads and clears gun.

No. 2 cleans barrel and replenishes water in barrel casing. (If necessary.)

No. 1 oils up, reloads and lays for direction.

Gun Commander puts on elevation.

No. 2 signals " Ready to Fire."

(xxiii.) " UNLOAD."—As in elementary drill. Gun Commander reports " No. 1 gun clear," " No. 2 gun clear," and so on.

(xxiv.) " OUT OF ACTION."—Guns dismounted at firing point.

Nos. 3, 4, 5 and 6 double forward and retire with aiming posts, belt boxes, " T " shaped bases, etc.

NOTE.—Interchange gun numbers as frequently as possible.

Fourth Stage.

(xxv.) Batteries should be practised in coming into action in different positions, obtaining parallel lines by different methods, and firing by barrage charts In the latter case verbal orders should be dispensed with as far as possible.

(xxvi.) In the final stages of training, batteries should be practised on the ground from the map of the district, and

Group Commanders should practise the Battery Commanders in applying the fire of their batteries to any target with rapidity and accuracy.

NOTE.—In elementary stages it may be found better for the Gun Commanders to pass orders rather than the Nos. 1.

8. RATES OF FIRE.

(i.) To prevent waste of S.A.A., to ensure time for re-laying and oiling (thereby prolonging the life of the gun), and to enable estimates of S.A.A. to be made in advance, rates of fire must be laid down for rigid observance by each gun.

(ii.) Normal rates of fire are:—

(*a*) *Slow fire.*—60—75 rounds per minute fired in bursts of 15—25.

This is the rate for long period barrage fire.

(*b*) *Medium fire.*—125—150 rounds per minute. This is the rate that can be used to speed up slow fire for short periods. It can be maintained for about half-an-hour, and should not be attempted for a longer period.

(*c*) *Rapid fire.*—250—300 rounds per minute. This rate is used in response to S.O.S. calls, but should only be maintained for a few minutes, after which the fire should be reduced to medium or slow rate.

(*d*) *Harassing fire.*—1,000 rounds per hour. This may be carried out at slow, medium, or rapid rates.

(iii.) Before ordering rates of fire, the following factors must be considered:—

(*a*) Tactical requirements of the barrage.

(*b*) Frontage per gun.

Obviously it will be necessary, if the concentration of guns is thin, to fire at a more rapid rate than if the concentration is thick, in order to produce the same result.

(*c*) Time during which the barrage is to be fired.

(*d*) Number of filled belts per gun available.

(*e*) Rate at which belts can be filled.

(*f*) Wear and tear of guns.

Assuming two belt-fillers per gun, and the rate of belt-filling by hand to be:—

4 belts per man the 1st hour.
3 ,, ,, ,, ,, 2nd hour.

If 14 belts per gun are available, then

(i.) It will be possible to fire 22 belts in one hour —*i.e.*, 5,500 rounds, but this will leave all the belts empty.

(ii.) It will be possible to fire 28 belts in two hours, *i.e.*, 3,500 rounds per hour.

It is the belt problem which imposes the "Slow Rate of Fire" for all long period barrages, and it is advisable to increase the number of belts per gun for large operations.

9. LIFE OF BARRELS.

The most important factors which affect the life of a barrel are:—

(i.) The temperature of the water.

(ii.) Oiling.

(*a*) With the rate of fire approximating 1,000 rounds per hour, fired intermittently, frequent oiling of the barrel, the water below boiling point or only boiling for short periods, the life of the barrel is 20,000 to 25,000 rounds.

This corresponds to "Harassing Fire."

(*b*) With a rate of fire exceeding 3,500 rounds per hour, fired continuously, frequent oiling of the barrel, the water boiling for long periods, the life of the barrel is 12,000 to 15,000 rounds.

This corresponds to normal forms of barrage fire and S.O.S. calls.

(*c*) A failure to oil the barrel in both the above cases at regular intervals appears to decrease the life by 3,000 to 4,000 rounds.

The loss of range due to worn barrels is not at present definitely known, but experiments have shown that the lengths of the beaten zones become nearly twice those given in the tables, and that the loss apparently does not exceed 5 per cent. of the range.

18.—COMMUNICATIONS.

(*See Part I., Section 29.*)

1. No proper fire control is possible without a comprehensive system of telephonic communications. This necessitates the most careful co-ordination of the machine gun signalling personnel available.

SYSTEM OF COMMUNICATIONS.

2. *Offensive Operations.*

(*a*) Forward Guns.—These can communicate through the Battalion report centre, in whose area they are operating. (*See* Sec. 4, para. 12, and Sec. 29, para. 2, of Part I.)

(*b*) Rear Guns.—Appendix III., A, shows the system where one group of guns is affiliated to one Brigade; when batteries move forward they connect to the Brigade Forward Station. When the Brigade Commander moves forward to the forward station the Group Commander accompanies him, and so keeps in touch with his batteries and Forward Observation Station.

3. *Trench Warfare.*

Appendix III., B., shows system for a Division with two Brigades in the line.

Owing to the necessity for Brigade and Battalion Commanders to be able to communicate quickly with Machine Gun Company Headquarters, and the necessity of keeping messages secret, Fullerphones are required at each Machine Gun Company Headquarters. In cases where sniping batteries are employed, these must be connected by telephone to a forward observation station, from which the controlling officer sends down the necessary fire orders to engage any target he wishes.

4. *Open Warfare.*

Companies should maintain their communications with Sections by signal or wire.

Brigades will be responsible for maintaining communications with Companies.

NOTE.—Further information on this subject is given in S.S. 191, *Intercommunication in the Field.*

APPENDIX I.

ORDERS FOR GUN POSITION No..........

1. Fire is only to be opened by order of the Gun Commander unless a sudden emergency arises, in which case the sentry will use his own initiative.
2. When relieving another gun team or sentry, the following facts will always be ascertained:—
   (*a*) Whether the gun has been fired during the relief.
   (*b*) If fired, what the target was.
   (*c*) If fired, the emplacement from which it was fired.
   (*d*) Whether any instructions have been received as to friendly patrols or wiring parties.
3. The sentry will always inspect the gun when taking over the position.
4. The sentry on duty must have an accurate knowledge of the targets shown on the fighting map.
5. In case of alarm, or a gas attack, the sentry will wake the gun team.
6. The gun will be cleaned daily, and the *points before firing* gone through both morning and night. The gun must be kept free from dirt, and in the trenches may be kept wrapped up in a waterproof sheet or bag. Such a covering must not prevent the gun being mounted for action immediately.
7. Ammunition, spare parts, and anti-gas apparatus will be inspected daily.
   The Gun Commander will be responsible that all anti-gas apparatus is always n position and in order.
8. The lock spring will never be left compressed.
   With the Vickers gun it is generally sufficient to half-load and then press the thumb-piece when mounting the gun at night. In order to open fire, it is only necessary to complete the loading motion and press the thumb-piece.
9. All dug-outs, emplacements and ammunition recesses belonging to the gun position must be kept clean and in good repair.

SPECIAL ORDERS FOR THIS GUN POSITION.

1. The S.O.S. signal is____________________
2. Action on S.O.S.____________________
3. Action if enemy penetrates our front line__________
4.
5.
6.

LIST OF STORES BELONGING TO THIS GUN POSITION.

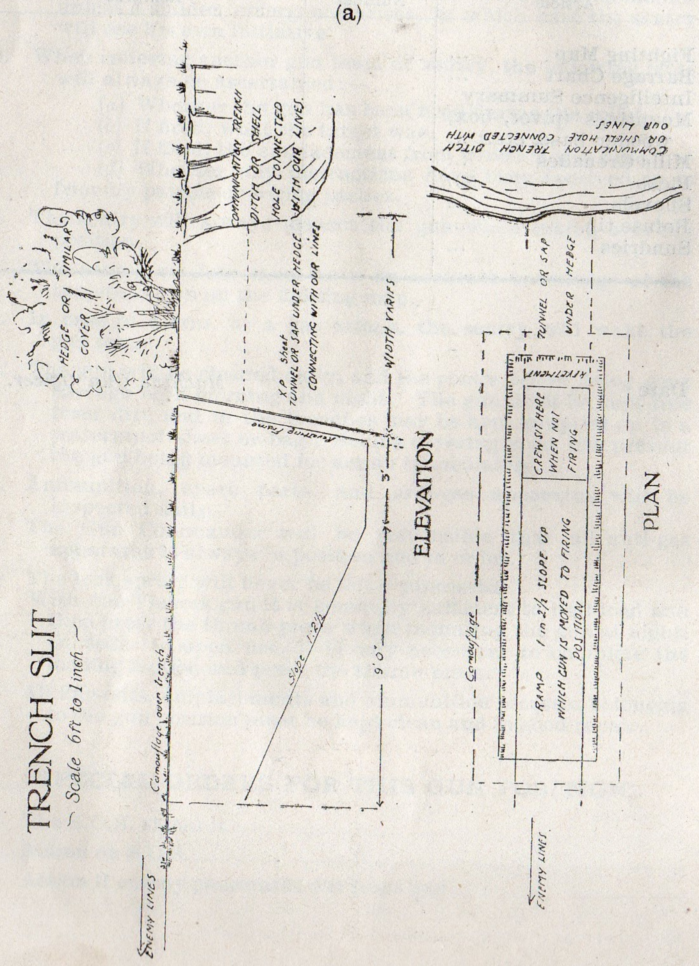
Article	Number	Remarks
Fighting Map ...		
Barrage Chart ...		
Intelligence Summary		
Mountings (pivot, box, wooden base, etc.) ...		
Mills Grenades ...		
Picks ...		
Shovels ...		
Refuse tin ...		
Sundries ...		

Date..................................   *Machine Gun Officer.*

APPENDIX II.

TYPES OF MACHINE GUN EMPLACEMENTS.

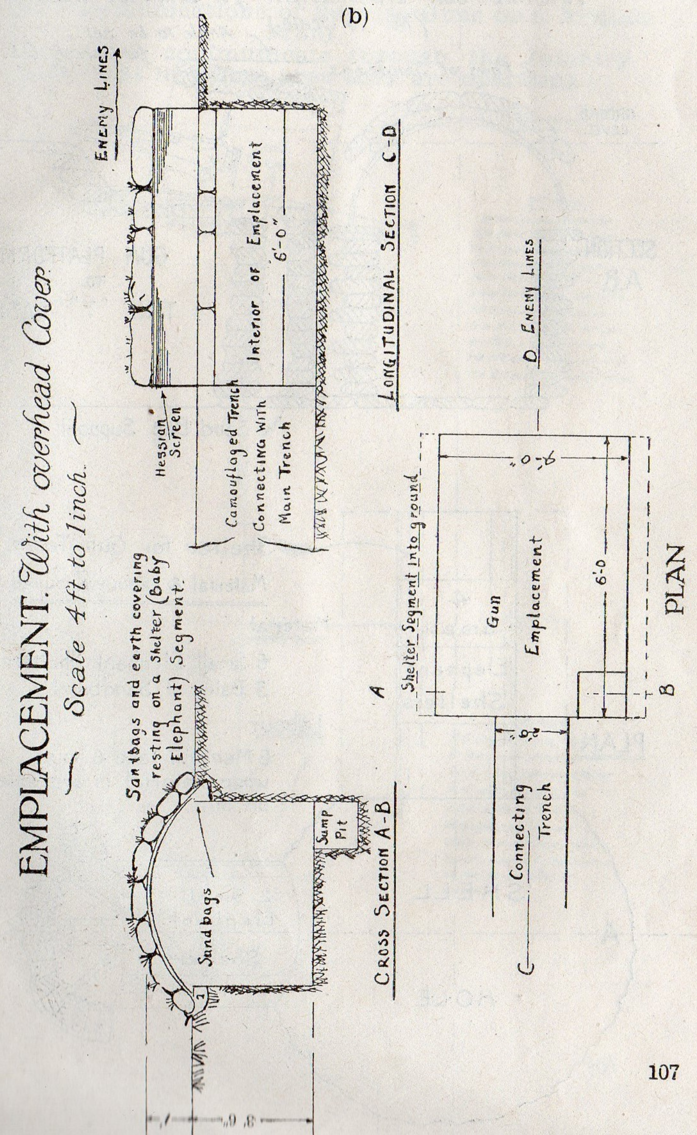
(a)



Appendix II.—*continued.*

Types of Machine Gun Emplacements—*continued.*

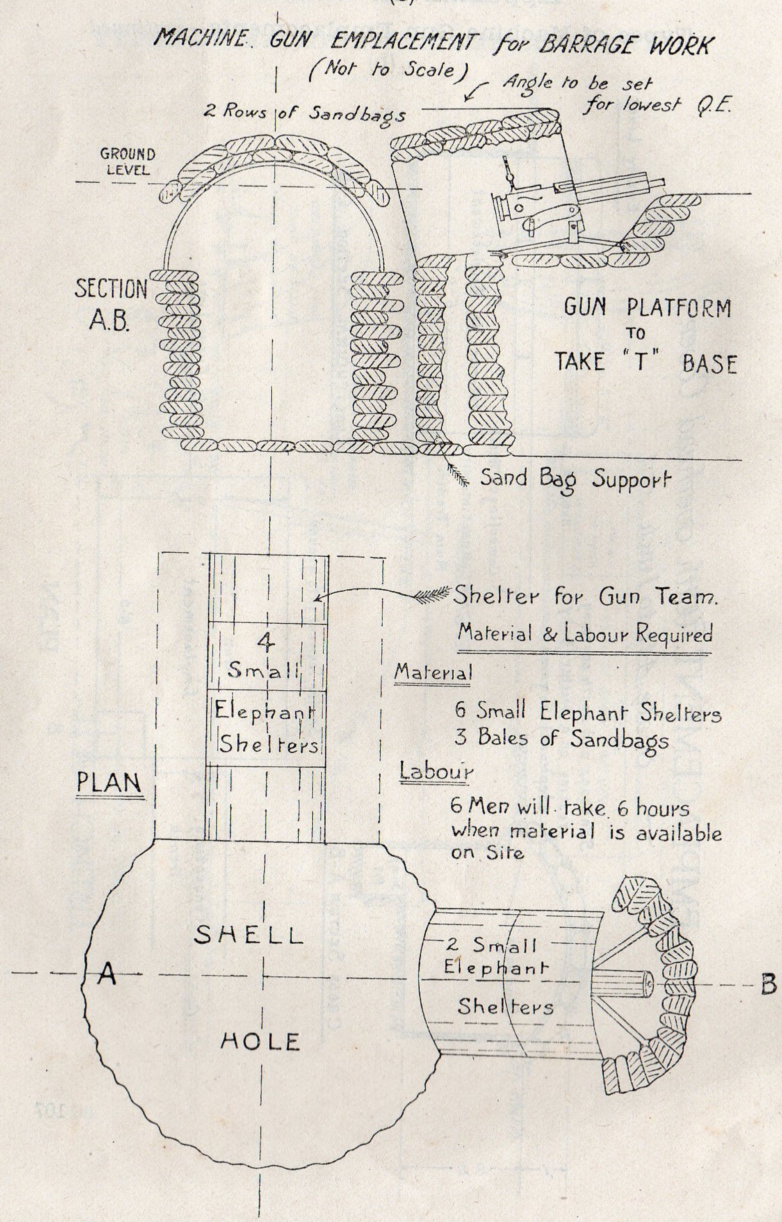
(b)



Appendix II.—*continued.*

Types of Machine Gun Emplacements.—*continued.*

(c)

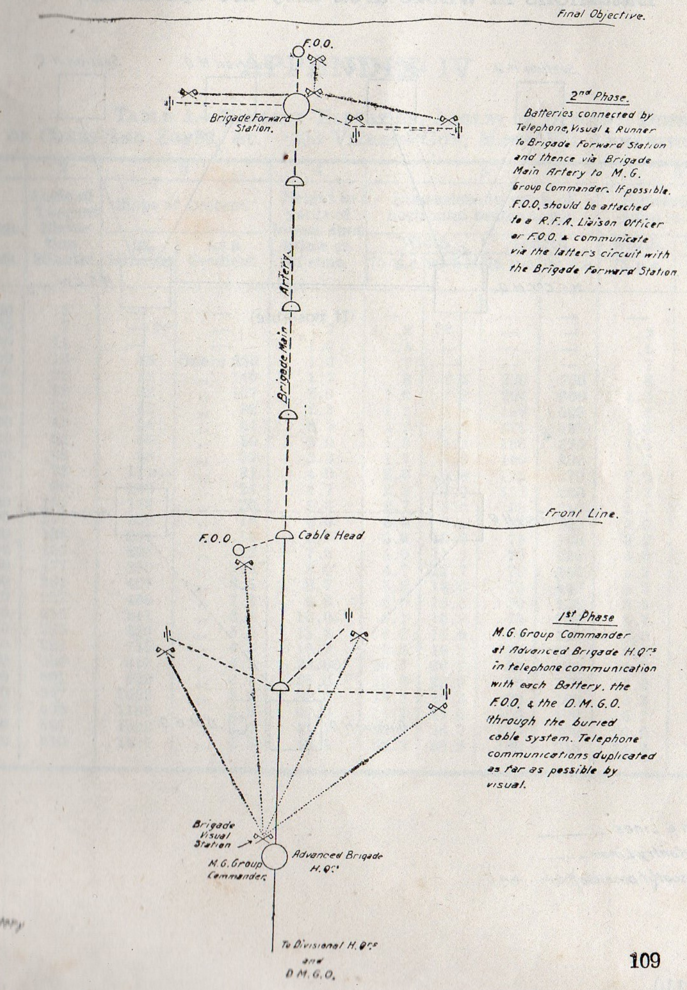


APPENDIX III.

A.—OFFENSIVE OPERATIONS.

Typical Communications of Barrage Guns on a Brigade Front.

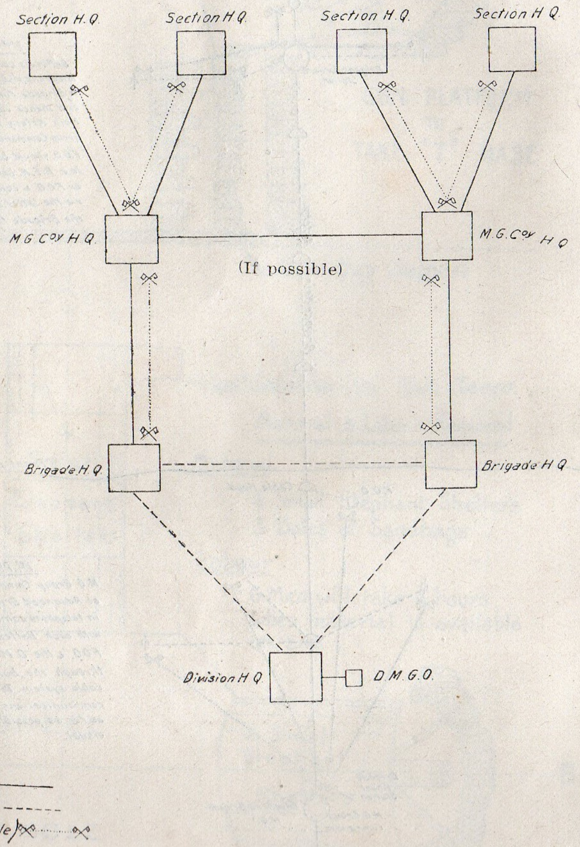
(Mobile Guns communicate through the Infantry Battalions in whose area they are operating.)



Appendix III.—*continued.*

B.—TRENCH WARFARE.

Typical Communications of Machine Guns on a Division Front.
(Forward sections communicate through the Infantry Battalions in whose area they are operating.)



APPENDIX IV.

TABLE 1.—TANGENT ELEVATION, ANGLES OF DESCENT, DIMENSIONS OF CONES AND ZONES, &c. ·303 VICKERS GUN, MARK VII AMMUNITION.

1	2	3		4	5				6	
Range.	Angle of Tangent Elevation.	Slope of Descent.		Height in yards of lowest shot below cr. of cone.	Dimensions in yards of horizontal beaten zones.				Dimensions of cones in yards.	
					Width.		Length.		Width.	Height.
Yards.	Minutes.	In Minutes.	As a Gradient.		75 p.c.	90 p.c.	75 p.c.	90 p.c.	75 p.c.	75 p.c.
100	3	—	—	—	—	—	—	—	—	—
200	7	—	—	.7	.3	—	—	—	.3	—
300	11	—	—	1.0	.5	—	—	—	.5	—
400	16	15	One in 230	1.3	.7	—	—	—	.7	—
500	22	23	,, 149	1.7	.8	2.3	220	700	.8	1.5
600	28	32	,, 107	2.0	1.0	2.8	204	600	1.0	1.9
700	35	42	,, 82	2.3	1.2	3.3	188	525	1.2	2.3
800	43	54	,, 64	2.7	1.3	3.8	172	450	1.3	2.7
900	52	69	,, 50	3.0	1.5	4.3	156	375	1.5	3.1
1000	62	88	,, 39	3.3	1.7	5.0	140	300	1.7	3.6
1100	73	111	,, 31	4.0	2.0	6.0	126	270	2.0	4.1
1200	86	139	,, 25	4.7	2.3	7.0	112	240	2.3	4.5
1300	101	172	,, 20	5.3	2.7	8.0	98	210	2.7	4.9
1400	117	209	,, 16	6.0	3.0	9.0	84	180	3.0	5.2
1500	135	251	,, 14	6.7	3.3	10.0	75	160	3.3	5.4
1600	155	298	,, 12	7.3	4.0	11.3	70	150	4.0	5.8
1700	177	350	,, 9.8	8.0	4.7	12.7	70	145	4.7	7.2
1800	201	407	,, 8.5	8.7	5.3	14.0	70	140	5.3	8.3
1900	227	469	,, 7.3	9.3	6.0	15.3	70	135	6.0	9.6
2000	256	541	,, 6.4	10.0	6.7	16.7	70	130	6.7	10.9
2100	288	623	,, 5.5	13.3	8.0	18.0	74	140	8.0	13.4
2200	322	715	,, 4.8	16.7	9.3	19.3	78	150	9.3	16.2
2300	360	817	,, 4.2	20.0	10.7	20.7	82	160	10.7	19.5
2400	401	929	,, 3.7	25.0	12.0	22.0	86	170	12.0	23.2
2500	447	1052	,, 3.3	30.0	13.3	23.3	90	180	13.3	27.2
2600	496	1186	,, 2.9	35.0	16.7	25.0	100	190	16.7	34.5
2700	551	1332	,, 2.6	41.7	20.0	26.7	110	200	20.0	42.3
2800	610	1491	,, 2.3	48.3	23.3	28.3	120	210	23.3	52.1

Appendix IV.—*continued.*

TABLE 2 (A). TRAJECTORY TABLE.

·303 VICKERS GUN. MARK VII AMMUNITION.

RANGE YARDS	POINT DISTANT FROM GUN IN YARDS.																										
	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800
0	·4	1·0	1·9	3·2	4·9	7·1	10·0	13·6	18·0	23·4	30·0	38·2	47·6	58·9	72·1	87·5	105	125	149								
100	·2	·7	1·5	2·8	4·4	6·5	9·3	12·8	17·2	22·4	28·9	37·0	46·4	57·0	70·7	86·0	104	124	147								
200	0	·4	1·1	2.2	3·7	5·7	8·4	11·8	16·0	21·1	27·6	35·5	44·8	55·9	68·9	84·0	102	121	145								
300	·3	0	·6	1·6	3·0	4·9	7·5	10·7	14·8	19·8	26·2	31·0	43·1	54·5	67·0	81·6	97·5	119	142								
400	·5	·5	0	·9	2·1	3·9	6·3	9·5	13·3	18·3	24·4	32·1	41·0	52·0	64·4	59·6	96·8	117	140								
500	·9	·9	·6	0	1·1	2·6	4·9	7·9	11·6	16·3	22·3	29·9	38·6	45·2	61·4	76·6	93·6	113	136								
600	1·2	1·4	1·3	·9	0	1·4	3·5	6·3	9·8	14·4	20·2	27·6	36·1	46·6	59·0	73·6	90·6	110	133								
700	1·6	2·0	2·1	1·9	1·2	0	1·9	4·5	7.9	12·2	17·8	25·0	33·3	43·6	55·8	70·1	87·0	106	128								
800	2·1	2·7	3·1	3·1	2·6	1·6	0	2·4	5·5	9·6	15·0	21.9	30·0	40·1	52·0	66·1	82·7	102	124								
900	2·6	3·5	4·1	4·4	4·2	3·5	2·0	0	2·9	6·7	11·9	18·5	26·4	36·2	48·0	61·7	78·0	96·6	119								
1000	3·2	4·3	5·3	5·8	5·9	5·5	4·4	2·6	0	3·5	8·7	14·7	22·4	31·8	43·2	56·9	72·8	91·1	113								
1100	3·9	5·4	6·6	7·5	7·9	7·8	7·1	5·6	3·3	0	4·5	10·6	17·9	27·0	38·2	51·4	67·0	85·0	106								
1200	4·6	6·5	8·1	9·3	10·2	10·3	10·1	9·0	7·1	4·2	0	5·7	12·6	21·4	32·1	45·0	60·1	78·0	98·9								
1300	5·5	7·8	9·5	11·5	12·7	13·4	13·5	12·8	11.3	8·6	5·1	0	6·5	14·8	25·1	37·5	52·3	69·5	90·0								
1400	6·4	9·2	11·7	13·8	15·5	16·7	17·2	17·0	16·0	13·9	10·6	6·0	0	7.9	17·7	29·6	43·9	60·7	80·8								
1500	7·3	10·7	13·7	16·3	18·7	20·3	21·3	21·7	21·9	19·7	17·0	12.7	7·3	0	9·3	20·7	34·6	50·8	70·4								
1600	8·7	12·7	16·0	19·3	22·0	24·3	26·0	27·0	27·0	26·0	24·0	20·4	15·3	8·7	0	10·9	24·1	39·7	58·6								
1700	10·0	14·3	18·7	22·7	26·0	29·0	31·3	32·7	33·3	33·0	31·7	28·7	24·3	18·3	10·0	0	12·6	27·6	45·9								
1800	11·3	16·7	21·3	25·0	30·5	33·8	36·7	39·0	40·3	40·7	40·0	37·7	34·3	28·7	21·3	12·0	0	14·3	32·0								
1900	13·0	19·0	24·7	30·0	35·0	39·1	43·0	46·0	48·3	49·3	49·3	48·0	45·0	40·3	33·7	25·0	14·0	0	16·8								
2000	14·3	21·3	27·7	34·0	39·7	45·0	49·7	53·3	56·7	58·3	59·3	58·7	56·7	53·0	47·3	39·3	29·0	16·0	0								
2100	16·3	24·3	31·7	38·7	45·3	51·7	57·0	62·0	65·7	68·7	70·7	70·7	69·8	66·7	62·0	54·7	45·7	33·7	18·7	0	—	—	—	—	—	—	—
2200	18·3	27·3	35·7	43·7	51·3	58·7	65·0	70·7	75·7	80·0	82·7	83·7	83·7	81·7	77·7	71·7	63·3	52·3	38·3	20·7	0	—	—	—	—	—	—
2300	20·7	30·7	40·0	49·3	58·3	66·3	74·0	80·7	86·3	92·0	96·0	98·0	99·0	98·3	95·7	90·7	83·3	73·7	60·7	44·0	24·0	0	—	—	—	—	—
2400	23·0	34·0	45·0	55·3	65·3	74·7	83·3	91·7	99·0	105	110	114	116	116	115	111	105	96·0	84·3	69·0	50·7	27·3	0	—	—	—	—
2500	25·7	38·0	50·0	62·0	73·3	84·0	94·3	104	112	120	126	131	135	136	136	134	129	121	111	97·0	79·7	58·0	31·7	0	—	—	—
2600	28·7	42·7	56·3	69·3	82·3	94·3	106	117	127	136	144	150	155	158	159	158	155	149	140	127	111	91·0	66·3	35·3	0	—	—
2700	32·3	47·7	62·7	77·7	92·0	106	119	132	143	153	163	171	178	182	185	186	184	180	172	161	147	128	105	75·7	41·7	0	—
2800	35·3	52·7	69·7	86·3	102	118	133	147	161	173	184	194	202	209	213	215	215	212	207	197	185	168	146	119	86·0	46·3	0
L.S.	·7	1·0	1·3	1·7	2·0	2.3	2·7	3·0	3·3	4·0	4·7	5·3	6·0	6·7	7·3	8·0	8·7	9·3	10·0	13.3	16·7	20·0	25·0	30·0	35·0	41·7	—

NOTES.

The table is divided into two parts, one below the zero line and the other above. That part below the zero line is the ordinary trajectory table; that part above and the words "positive" and "negative" are for use when determining clearance in Indirect Overhead Fire. See Section 10, Notes para. vii.

PART BELOW ZERO LINE.

1.—This table gives at any distance from the gun the height IN YARDS of the centre of the cone ABOVE the line of sight. When used for clearance, line of sight is taken to be horizontal.

EXAMPLE.—At a range of 1900 yards, and at a distance of 1000 yards from the gun the centre of the cone is 48·3 yards above the line of sight.

2.—To find the height of the lowest shot above the line of sight SUBTRACT the figure in the line marked L.S. from the height of the trajectory.

EXAMPLE.—At a range of 1800 yards the lowest shot at 900 yards from the gun is 39 — 3 = 36 yards above the line of sight.

PART ABOVE ZERO LINE.

1.—This table gives at any distance from the gun the depth IN YARDS of the centre of the cone BELOW a horizontal plane passing through the gun position. When using this table the range is not the range to the target, but is the quadrant angle on the gun converted to a range by Table 1, column 2.

EXAMPLE.—At a range of 800 yards, and at a distance of 1200 yards from the gun the centre of the cone is 15 yards below the horizontal plane through the gun position.

2.—To find the depth of the lowest shot below the horizontal plane passing through the gun position ADD the figure in the line L.S. to the height of the trajectory.

EXAMPLE.—At a range of 800 yards, the lowest shot at 1400 yards from the gun is 30 plus 6 = 36 yards below the horizontal plane through the gun position.

Appendix IV.—*continued.*

TABLE 2 (B).—TRAJECTORY TABLE FOR NEGATIVE QUADRANT ANGLES.
·303 VICKERS GUN, MARK VII AMMUNITION.

Q.E. Mins.	Distance of Point from Gun in Yards.															
	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
-5	.7	.9	1.0	1.2	1.3	1.4	1.6	1.7	1.9	2.0	2.1	2.3	2.5	2.6	2.7	2.9
-0	3.2	4.8	7.1	10.0	13.6	18.0	23.4	30.0	38.2	47.6	58.9	72.1	87.5	105	125	149
-25	6.8	9.2	12.2	15.8	20.2	25.3	31.7	39.1	47.6	57.6	69.7	83.7	99.6	118	139	163
-50	10.4	13.6	17.3	21.6	26.7	32.6	39.7	47.8	57.1	67.8	80.6	95.5	112	131	153	178
-75	14.1	17.9	22.4	27.4	33.2	39.8	47.8	56.5	66.6	78.0	91.6	107	124	144	167	192
-100	17.7	22.3	27.6	33.2	39.8	47.2	55.6	65.4	76.0	88.4	102	119	137	158	180	207
-125	21.3	26.8	32.7	38.0	46.4	54.5	63.6	74.0	85.5	98.5	113	130	149	171	194	221
-150	24.9	31.1	37.8	44.7	52.9	61.6	71.6	82.8	95.0	109	124	142	162	184	208	236
-175	28.5	35.4	42.9	50.5	59.5	68.9	79.6	91.5	104	119	135	154	174	197	222	250
-200	32.2	39.7	47.8	56.4	66.1	76.1	87.6	100	114	129	146	164	186	210	236	265
-225	35.6	44.1	52.9	62.2	72.7	83.4	95.6	109	123	139	157	177	199	223	250	279
-250	39.5	48.4	58.2	68.0	79.0	90.7	104	118	133	149	168	188	211	236	264	294
-275	42.8	52.8	63.3	73.8	85.6	98.0	112	126	142	159	179	200	224	249	277	308
-300	46.8	57.1	68.4	79.6	92.1	105	120	135	152	169	190	211	236	262	291	323
-325	50.0	61.5	73.2	85.4	98.6	113	128	144	161	180	201	223	248	275	305	
-350	54.1	65.8	78.3	91.2	105	120	136	152	171	190	212	235	261	288		
-375	57.2	70.2	83.4	97.0	112	127	144	161	180	200	223	246				
-400	61.3	74.5	88.5	103	118	134	152	170	189	210	234					
-425	65.0	78.9	93.6	109	125	142	160	179	199	220	244					
-450	68.6	83.2	98.7	115	131	149	168	189	208	230	255					
-475	72.2	87.6	104	120	138	156	176	196	218	240						
-500	75.9	92.1	109	126	145	163	184	205	227							
-525	79.5	96.5	114	132	151	170										
-550	83.1	101	119	138	158	178										

NOTES.

1.—This table gives at any distance from the gun the depth IN YARDS of the centre shot of the cone below a horizontal plane passing through the gun position.

2.—It is for use when determining clearance over our own troops, heads in indirect overhead fire.

3.—The line Q.E. = − 5 means that at 1000 yards, for instance, each addition of 5 minutes to the Q.E. adds 1·5 yards to the depth of the trajectory.

EXAMPLE.

Q.E. = − 265 minutes; range = 1400 yards. Trajectory depth below horizontal plane = 149 plus 2 yards for each 5 minutes added above 250.
= 149 + ($\frac{15}{5}$ × 2) = 155.

Appendix IV.—*continued.*

TABLE 3 (A).—THE QUADRANT ANGLE IN MINUTES, KNOWING RANGE AND V.I. ·303 VICKERS GUN, MARK VII. AMMUNITION.

Target ABOVE Gun.

V.I. in Yards.	Range to Target in Yards.																						
	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800
1	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1
5	56	57	60	65	71	79	89	100	114	129	147	166	187	211	236	265	296	330	368	408	454	503	557	616
10	91	85	84	86	90	96	104	115	127	142	158	177	197	220	245	273	304	338	375	415	461	509	564	622
15	125	114	109	108	109	114	120	129	141	154	169	187	207	230	254	282	313	345	382	423	468	516	570	628
20	160	143	133	129	129	131	136	143	154	166	181	198	218	239	263	290	321	353	390	430	475	522	577	635
25	194	171	158	151	148	148	151	158	167	178	192	209	228	249	272	299	329	361	397	437	481	529	583	641
30	228	200	183	172	167	165	167	172	181	191	204	220	238	258	231	308	337	369	405	444	488	536	589	647
35	263	229	207	194	186	183	183	186	194	203	215	230	248	268	291	316	345	377	412	451	495	542	596	653
40	297	258	232	215	205	200	198	201	207	215	227	241	258	278	300	325	354	385	420	458	502	549	602	659
45	332	286	256	237	224	217	214	215	220	228	238	252	268	287	309	334	362	392	427	465	509	556	608	665
50	366	315	281	258	243	234	229	229	233	240	250	263	278	297	318	342	370	400	435	473	516	562	615	672
55	400	344	305	279	262	251	245	244	247	252	261	273	288	306	327	351	378	408	442	480	523	569	621	678
60	435	372	330	301	281	268	261	258	260	265	273	284	299	316	336	359	386	416	450	487	530	576	628	684
65	469	400	354	323	300	285	276	272	273	277	284	295	309	325	345	368	394	424	457	494	537	582	634	690
70	503	429	379	344	319	303	292	287	286	289	296	306	319	335	353	376	402	432	465	501	544	589	640	696
75	538	458	403	366	338	320	307	302	300	302	307	316	329	344	362	385	411	440	472	509	550	596	646	703
80	572	486	428	387	358	337	323	317	313	314	319	327	339	354	372	394	419	448	480	516	557	603	652	709
85	606	515	452	408	377	354	339	331	327	327	330	338	349	363	381	403	427	456	487	523	564	609	659	715
90	641	544	477	429	396	371	354	346	340	339	342	348	359	373	390	411	436	464	495	530	571	616	665	721
95	675	572	502	451	415	389	370	360	353	351	353	359	369	383	399	420	444	471	502	538	577	622	671	727
100	708	602	526	472	434	406	386	375	366	363	364	370	379	392	408	429	452	479	510	545	584	629	678	733

NOTES.

1.—This table combines the angle of sight with the angle of tangent elevation, thereby producing the quadrant angle directly.
2.—It is used as follows :—Range = 1900 yards. Target 55 yards above gun. Quadrant elevation = 327 minutes.
3.—The top line where V.I = 1 yard is used as follows :—EXAMPLE I : Range = 1900, V.I. = 57 yards. The quadrant elevation for range = 1900 and V.I. = 55 is 327 minutes. For each extra yard of V.I. the top line shows that 2 minutes must be ADDED. Therefore necessary quadrant angle is 327 plus (2 × 2) = 331 minutes.

Appendix IV.—*continued.*

TABLE 3 (B).—THE QUADRANT ANGLE IN MINUTES, KNOWING RANGE AND V.I. ·303 VICKERS GUN, MARK VII. AMMUNITION.

Target BELOW Gun.

V.I. in Yards.	Range to Target in Yards.																						
	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800
1	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1
5	-12	-1	10	21	33	45	57	72	88	105	123	144	167	191	218	248	280	314	352	394	440	489	545	604
10	-47	-29	-14	0	14	28	42	57	75	92	112	133	157	182	209	239	272	306	345	387	433	483	538	598
15	-81	-58	-39	-22	-5	10	26	43	61	80	101	123	147	172	200	230	263	299	338	379	426	476	532	592
20	-116	-87	-64	-43	-25	-7	10	29	48	68	89	112	136	163	191	222	254	291	330	372	420	470	525	585
25	-150	-115	-88	-65	-44	-24	-5	14	35	50	78	101	125	153	182	213	247	283	323	365	413	463	519	579
30	-184	-144	-113	-86	-63	-41	-21	0	21	43	66	90	116	144	173	204	239	275	315	358	406	456	513	573
35	-219	-173	-137	-108	-82	-59	-37	-14	8	31	55	80	106	134	164	196	231	267	308	351	390	450	506	567
40	-253	-202	-162	-129	-101	-76	-52	-29	-5	19	43	69	96	124	155	187	222	259	300	344	392	443	500	561
45	-288	-230	-186	-151	-120	-93	-68	-43	-18	6	32	58	86	115	146	178	214	252	293	336	385	436	494	555
50	-322	-259	-211	-172	-139	-110	-83	-57	-31	-6	20	47	76	105	137	170	206	244	285	329	378	430	487	548
55	-357	-288	-235	-193	-158	-127	-99	-72	-45	-18	9	37	66	96	128	161	198	236	278	322	371	423	481	542
60	-391	-316	-260	-215	-177	-144	-115	-86	-58	-31	-3	26	55	86	119	153	189	228	270	315	364	416	474	536
65	-425	-344	-284	-237	-197	-161	-130	-100	-71	-43	-14	15	45	77	110	144	181	220	263	308	358	410	468	530
70	-460	-372	-309	-258	-216	-179	-146	-115	-84	-55	-26	5	35	67	101	136	173	212	255	301	351	403	462	524
75	-495	-401	-333	-280	-235	-196	-161	-129	-97	-67	-37	-6	25	57	92	128	166	206	248	294	344	397	456	518
80	-529	-430	-358	-301	-254	-214	-177	-144	-111	-79	-48	-17	15	48	82	119	158	199	240	287	337	391	449	512
85	-563	-459	-382	-323	-273	-231	-192	-158	-124	-92	-60	-28	5	38	73	111	149	191	233	280	330	384	443	506
90	-598	-488	-407	-344	-292	-248	-208	-172	-137	-104	-71	-39	-5	29	64	102	141	183	225	273	323	378	436	500
95	-632	-517	-431	-366	-311	-265	-223	-186	-150	-117	-83	-50	-15	19	55	93	132	175	218	266	316	371	430	494
100	-666	-545	-456	-387	-330	-282	-239	-200	-163	-129	-94	-60	-25	10	46	85	124	167	210	259	310	365	424	488

NOTES.

1.—This table combines the angle of sight with the angle of tangent elevation, thereby producing the quadrant angle directly.
2.—It is used as follows :—Range = 1900 yards. Target 55 yards below gun. Quadrant elevation = 128 minutes.
3.—The top line where V.I. = 1 yard is used as follows :—EXAMPLE I : Range = 1900 yards. Target 57 yards below gun. The quadrant angle for range = 1900 and V.I. = 55 is 128 minutes. For each extra yard of V.I. the top line shows that 2 minutes must be SUBTRACTED. Therefore necessary quadrant angle is 128 − (2 × 2) = 124 minutes. EXAMPLE II : Range = 1300 yards, V.I. = 38 yards, Q.E. = 8 − (3 × 3) = − 1 minute. EXAMPLE III : Range = 1100 yards, V.I. = 47 yards, Q.E. = − 68 − (2 × 3) = − 74 minutes.

Appendix IV.—*continued.*

TABLE 4.—ATMOSPHERIC ALLOWANCE (in minutes).

NORMAL RANGE.		1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800		
HEAD WINDS ADD — REAR WINDS DEDUCT.	M.P.H.																				M.P.H.	M.P.H. × 3/2 = FEET per SECOND.
	5	0	1	1	1	2	2	2	2	3	4	5	6	7	8	10	12	15	17	22	5	
	10	1	1	2	2	3	4	4	4	6	8	9	11	14	17	20	24	30	37	44	10	
	15	1	2	3	3	4	6	6	6	9	11	13	17	22	27	30	37	44	58	67	15	
	20	2	2	4	4	5	8	8	9	13	15	17	23	29	34	40	49	60	75	89	20	
	25	2	3	4	5	6	10	10	12	16	19	24	29	36	43	50	61	75	92	112	25	
	30	3	4	5	6	8	12	12	16	19	23	30	35		51	60	73	91	109	136	30	
	35	3	4	6	7	11	14	14	19	24	27	35	40	50	59	70	87	107	119	167	35	
BARO-METER ABOVE 30" ADD.	30·2"	0	1	1	1	1	1	2	2	2	2	2	3	3	4	5	5	5	6	6	29·8"	BELOW 30" DEDUCT.
	30·4"	0	1	1	2	2	2	2	2	4	4	4	5	5	7	7	8	8	9	10	29·6"	
	30·6"	1	1	2	2	3	3	3	3	5	5	5	6	7	8	9	10	12	13	16	29·4"	
	30·8"	1	1	2	3	3	4	4	4	7	7	7	8	9	10	11	12	15	17	22	29·2"	
	31·0"	1	2	3	3	4	4	4	5	8	8	9	11	12	13	14	15	20	23	25	29·0"	
TEMPERA-TURE (FAH.) ABOVE 60° DEDUCT.	65°	0	1	1	1	1	1	2	2	3	3	3	5	6	6	7	7	8	8	9	55°	BELOW 60° ADD.
	70°	1	1	2	2	3	3	3	3	6	6	6	7	7	10	10	12	14	16	18	50°	
	75°	1	2	3	3	4	4	4	5	7	8	9	11	12	13	14	18	20	25	28	45°	
	80°	2	2	4	4	5	6	6	7	9	11	12	14	16	18	20	24	29	33	36	40°	
	80°	2	3	4	5	6	8	8	9	11	13	15	17	20	22	25	30	36	41	44	35°	
	90°	3	4	5	6	7	9	9	11	13	15	18	21	24	27	30	36	42	48	52	30°	
	95°	3	4	5	7	8	11	11	13	16	17	21	24	27	31	35	42	49	55	60	25°	
	100°	4	5	6	8	10	12	14	16	19	20	24	28	32	36	40	48	56	63	70	20°	
	105°	4	6	7	9	11	13	16	18	21	23	27	32	36	41	45	54	62	72	80	15°	
	110°	5	6	8	9	12	15	17	20	23	26	31	35	40	45	50	59	68	78	89	10°	
	115°	5	7	9	10	13	16	18	22	25	28	35	39	44	50	56	63	74	85	98	5°	
	120°	6	7	10	11	14	17	20	23	26	31	37	43	49	56	63	70	81	92	106	0°	

NOTE.—Normal atmospheric conditions = still air. Barometer 30". Temperature 60°F.
Convert Oblique Winds and thus get the equivalent Head and Rear Wind by Appx. 4, Table 5.

EXAMPLE :—Map Range 2400 yds. (QE.401'). Wind 15 M.P.H. "Head." Barom. 29·6" Temp. 50°F. To get corrected QE. =
(1) Find 2400 yds. in column "Normal Range."
(2) Find necessary allowance for Head Wind 15 M.P.H. = + 30'.
(3) Find allowance for Barom. 29·6" = − 7'.
(4) Find necessary allowance for Temp. 50°F. = + 10'.
(5) + 30' − 7' + 10' = + 33'.
(6) ADD 33' to 401' = *434' Corrected QE.*

Appendix IV.—*continued.*

TABLE 5.—LATERAL WIND ALLOWANCES.

Range Yards	Mild 10 M.P.H.		Fresh 20 M.P.H.		Strong 30 M.P.H.	
	Yards	Minutes	Yards	Minutes	Yards	Minutes
500	1	5	1½	10	2	15
1000	3	10	6	20	9	30
1500	6	15	12	30	18	45
2000	12	20	24	40	36	60
2500	24	30	48	60	72	90

OBLIQUE WIND ALLOWANCES.

Angle of Wind with Line of Fire	Ratio of Wind affecting Elevation	Ratio of Wind affecting Direction
10° 20°	1	¼
30° 40°	¾	½
50° 60°	½	¾
70° 80°	¼	1

TABLE 6.—TIME OF FLIGHT.

Time of Flight in Seconds.	Distance Traversed in Yards.
1	600
2	1000
3	1300
4	1550
5	1775
6	1950
7	2100
8	2225
9	2350
10	2450
11	2550
12	2625
13	2700
14	2775
15	2840

Appendix IV.—*continued.*

TABLE 7.

SEARCHING REVERSE SLOPES.

·303 VICKERS GUN. MARK VII. AMMUNITION.

All Figures represent Yards.

1	2	3	4	5	6	7	8	9	10	11	12	Gun Above or Below Crest	12	11	10	9	8	7	6	5	4	3	2	1
1500	1600	1650	1700	1850	1850	1900	1950	2000	2000	2050	2100		1900	1800	1700	1600	1500	1400	1400	1350	1300	1300	1300	1200
1350	1400	1500	1600	1650	1700	1800	1850	1900	1950	2000	2050	0	2050	2000	1950	1900	1850	1800	1700	1650	1600	1500	1400	1350
1400	1450	1550	1600	1700	1750	1800	1850	1900	1950	2000	2050	10	2000	1950	1900	1850	1800	1750	1650	1600	1550	1450	1300	1150
1450	1500	1550	1650	1700	1750	1850	1900	1950	2000	2050	2100	20	2000	1950	1850	1800	1700	1650	1600	1550	1450	1350	1200	
1500	1500	1600	1650	1750	1800	1850	1900	1950	2000	2050	2100	30	1950	1900	1850	1750	1650	1600	1550	1500	1400	1250	1100	
1500	1550	1650	1700	1750	1800	1900	1950	1950	2000	2050	2100	40	1900	1850	1800	1700	1600	1500	1450	1450	1300	1150		
1550	1600	1700	1700	1800	1850	1900	1950	2000	2050	2100	2100	50	1900	1850	1750	1650	1550	1450	1400	1350	1200			
1600	1650	1700	1750	1800	1850	1950	2000	2000	2050	2100	2150	60	1850	1800	1700	1600	1450	1400	1350	1300				
1650	1650	1750	1750	1850	1900	1950	2000	2050	2100	2150	2150	70	1800	1750	1650	1550	1400	1300	1300	1700				
1650	1700	1800	1800	1850	1900	1950	2000	2050	2100	2150	2150	80	1750	1750	1650	1500	1350	1250	1250					
1700	1750	1800	1800	1900	1950	2000	2050	2050	2100	2150	2200	90	1750	1700	1600	1450	1250	1150						
1750	1800	1850	1850	1950	1950	2000	2950	2100	2150	2200	2200	100	1700	1650	1550	1400	1200	1100						
1800	1850	1900	1900	1950	2000	2050	2100	2100	2150	2200	2200	110	1650	1600	1500	1350	1150							
1850	1850	1900	1950	2000	2000	2050	2100	2100	2150	2200	2200	120	1600	1550	1450	1300	1100							
1850	1900	1950	1950	2000	2050	2050	2100	2150	2200	2250	2250	130	1600	1550	1450	1250								
1900	1950	1950	2000	2050	2050	2100	2150	2150	2200	2250	2250	140	1550	1500	1400	1200								
1900	2000	2000	2050	2050	2100	2100	2150	2150	2200	2250	2250	150	1500	1450	1350	1150								
	2000	2050	2050	2100	2100	2150	2200	2200	2250	2300	2250	160	1450	1400	1300									
		2050	2100	2150	2150	2150	2200	2200	2250	2300	2300	170	1400	1350	1250									
			2100	2150	2150	2200	2200	2250	2250	2300	2300	180	1400	1350										
					2200	2200	2250	2250	2300	2300	2350	190	1350	1300										
							2250	2250	2300	2350	2350	200	1300											

Gun below Crest. **Gun above Crest.**

NOTES.

1.—The top horizontal line is the drop IN YARDS in the first 100 yards beyond the crest. The horizontal line directly below it is the distance to measure back from the crest to find gun position.

NOTE.—The crest may be taken as being either the highest point of the ground, or, in the case of a flat-topped hill, the point at which a gentle slope changes to a more abrupt one.

2.—EXAMPLE.—The ground drops 7 yards in 100, and assume also that the gun is below the crest. The left-hand side of table must therefore be used. The table shows that for a drop of 7 yards we must go back 1900 yards from the crest. At this point, say, the gun position is found to be 90 yards below the crest. Final range, therefore, equals 2000 yards. Place the gun at this point.

3.—When the gun is in position, fire should be directed on the crest, elevation and direction being put on by any of the usual methods for indirect fire. In the example given above, the quadrant angle is that for a V.I. of 90 yards and a range of 2000 yards—*i.e.*, 411 minutes. See Table 3 (A).

4.—Searching should be employed away from the crest, but it must be remembered that as the cone is beating falling ground the length of the zone will be very much increased; therefore the turns of the wheel should be few in number.

5.—If the final position is not suitable, the gun should be moved further away from—not nearer to—the crest.

6.—If it be desired to engage an area of ground which lies some distance back from the crest, without searching back from the crest itself, the position of the gun must be determined with reference to the crest as detailed above. Then the quadrant elevation necessary to hit the near limit of the ground to be searched must be put on in the usual way for indirect fire.

IN YARDS
IN METR

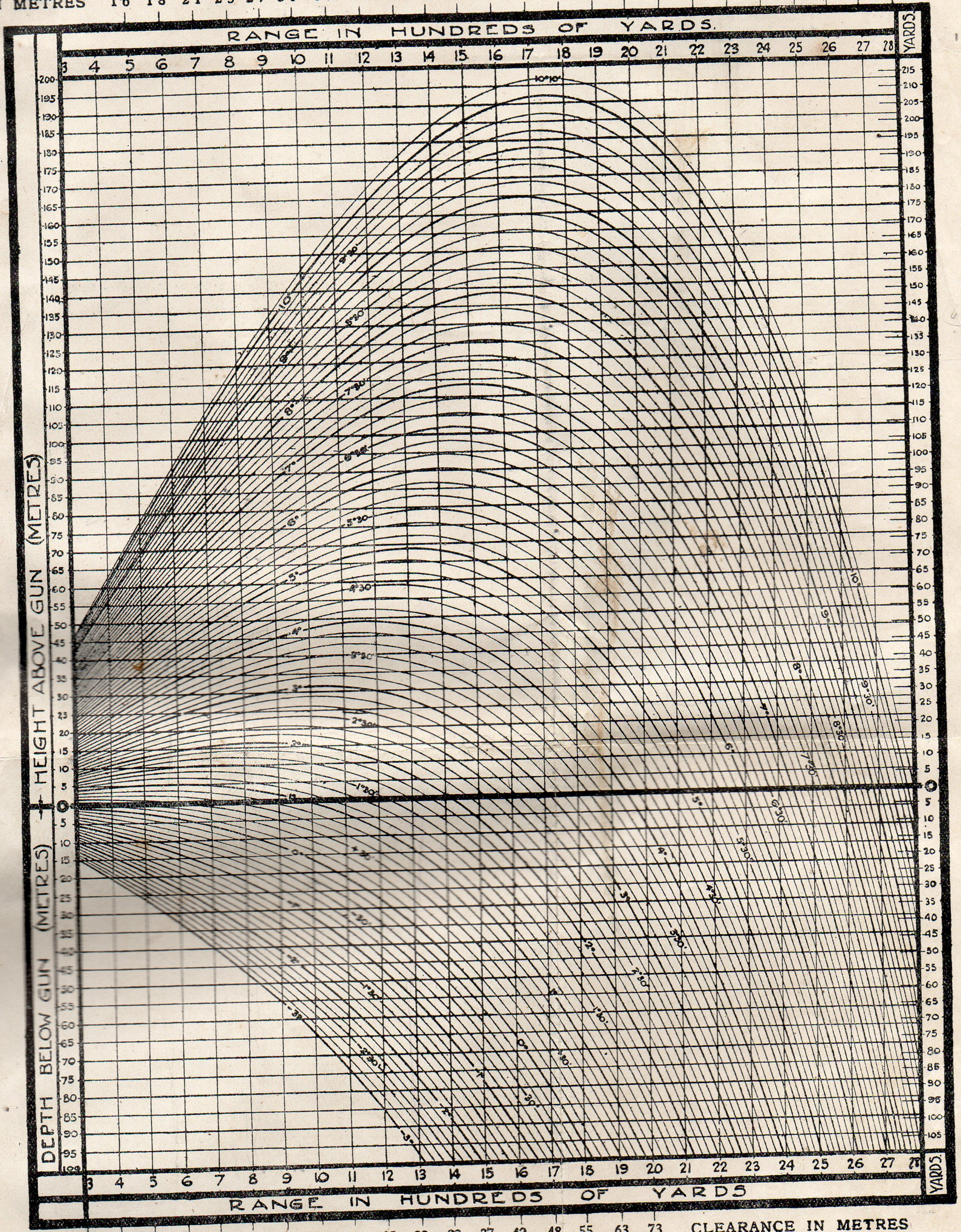
No. 1.

GRAPH FOR CALCULATING QUADRANT ELEVATION AND CLEARANCES.

(CURVES REPRESENT CENTRE SHOTS.)

DEPTH OF LOWEST SHOT BELOW CENTRE OF CONE AT VARIOUS DISTANCES FROM GUN.

IN YARDS ..	1·7	2·0	2·3	2·7	3·0	3·3	4·0	4·7	5·3	6·0	6·7	7·3	8·0	8·7	9·3	10	13·3	16·7	20	25	30	35	42	48
IN METRES	1·6	1·8	2·1	2·5	2·7	3·0	3·7	4·3	4·8	5·5	6·1	6·7	7·3	8·0	8·5	9·1	12·2	15·3	18·3	23	27	32	38	44



10	10	10	10	12	14	16	18	21	25	28	32	37	42	48	55	63	73	CLEARANCE IN METRES
11	11	11	11	13	15	17	20	23	27	31	35	40	46	53	60	69	80	CLEARANCE IN YARDS

MINIMUM CLEARANCES REQUIRED AT VARIOUS DISTANCES FROM GUN.

HOW TO USE THE GRAPH.—TO FIND Q.E. : Take range and run up on vertical scale to height of target above or below gun. The curve cutting this point gives required Quadrant Elevation.

TO FIND CLEARANCE.—Follow this curve along, and ascertain at what height it passes vertically above a point plotted at the distance and height (above or below gun) of own troops (or obstruction). This gives clearance in yards

No. 2.

GRAPH *of* TRAVERSES, *etc.*

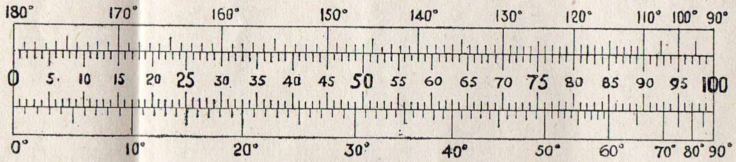
(IN YARDS OR METRES AND DEGREES)

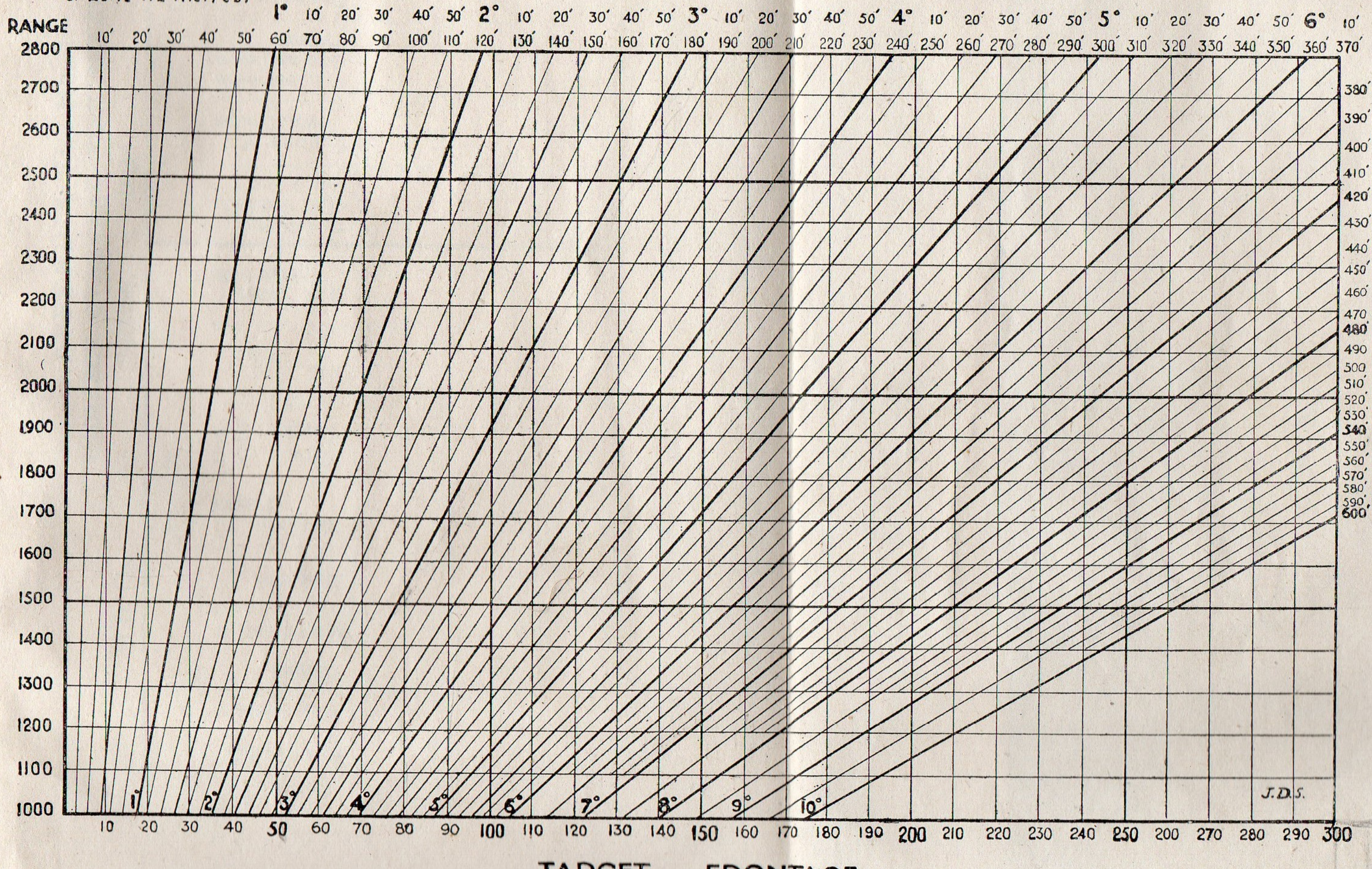
The Angle is shewn by the diagonal line nearest to the point of intersection of the required Target-Frontage line (vertical) and the (horizontal) Range line.

Note:— Both Target Frontage and Range must be taken in the same unit of measure: e.g. both in yards or both in metres.

SCALE *for the* conversion *of* **OBLIQUE** *to* equivalent **FRONTAL TARGETS.**

EXAMPLE :— *Target 280ˣ long at an angle of 150° to line of fire. The scale gives ·45 so equivalent frontal target = ·45 of 280ˣ = 126ˣ*





APPENDIX VI. No. 1.
INDIRECT OVERHEAD FIRE SHEET.

No.………M.G. Co.   No.………Section.   Date……………   Map used…………………

Elevation										Clearance						
Gun position	Map location	Target	Map location	Direction	Range to Target	Contours		V.I. + or V.I. −	Q.E. Table 3 (A) or 3 (B)	Range for Q.E. Table 1, Col. 1 and 2	Contour of own Troops	V.I. between Gun and own Troops	Range to own Troops	Trajectory Height Table 2 (A) or 2 (B)	Clearance obtained	Table of Safety Clearances
						Gun	Target									
																600 – 11 × 700 – 13 × 800 – 15 × 900 – 17 × 1000 – 20 × 1100 – 23 × 1200 – 27 × 1300 – 31 × 1400 – 35 × 1500 – 40 × 1600 – 46 × 1700 – 53 × 1800 – 60 × 1900 – 69 × 2000 – 80 ×
																Grid bearing of Zero Line

Appendix VI.—*continued.* No. 2.

Ref.: 1/1000.

BATTERY CHART. D. Battery.

Place:
Date:

Composition No. 3 and 4 Sections No. M.G.C.	Frontage of Battery 70 yards.	TASK:— Creeping Barrage, move forward to advanced battery position. D.2.
Commanded by:	Grid Bearing to R.O. 31° 30′	
Location of Directing Gun 7d. 50°. 23.	Zero Line 7d. 50. 23. through 6a 1.5.	
No. of Directing Gun. No. 8	Grid Bearing of Zero Line 290° 30′	

No. of Barrage	No. of Guns	Targets	Clock Times	Zero Time	Angle of Switch.	Distribution Angle	Range	V.I.	Q.E.	Range to F.T. when Barrage Lifts	Clearance when Barrage Lifts	Rate of Fire
A	1 to 8	2c 1.1. to 6a 1.5.		Z to Z + 2	0°	50′	1800	−8x	3° 5′	1150x	39x	75 R.P.M.
B	1 to 8	1d 7.1. to 5b 7.5.		Z + 3 to Z + 5	1° 30′ L	50′	2000	−10x	4°	1250x	58x	75 R.P.M.
C	1 to 8	1d 3.1. to 5b 3.5.		Z + 6 to Z + 8	3° L	40′	2200	−5x	5° 14′	1350x	87x	75 R.P.M.

	8	7	6	5	4	3	2	1	REMARKS.
A	0°	50′ R	1′ 40 R	2° 30′ R	3° 20′ R	4° 10′ R	5° R	5° 50′ R	This shews angle of Deviation from Zero Line for each gun. From this Table a Barrage Chart for each gun is compiled and issued to Gun Commanders.
B	1° 30′ L	40′ L	10′ R	1° R	1° 50′ R	2° 40′ R	3° 30′ R	4° 20′ R	To get parallel lines all guns 101° 30′ Left. (NOTE:—The R.O. was in line with the guns).
C	3° L	2° 20′ L	1° 40 L	1° L	20′ L	20′ R	1° R	° 40′ R	

Appendix VI.—*continued.* No. 3.

GUN CHART.

No. 1 Gun. D. Battery. Gun Commander:—

Grid Bearing of Zero Line 290° 30′

No. of Barrage	Clock Time	Zero Time	Angle from Zero Line	Q.E.	Traverse	Rate of Fire
A		0 to 2	5° 50′ R	3° 5′	2°	75 R.P.M.
B		3 to 5	4° 20′ R	4°	2°	75 R.P.M.
C		6 to 8	1° 40′ R	5° 14′	2°	75 R.P.M.

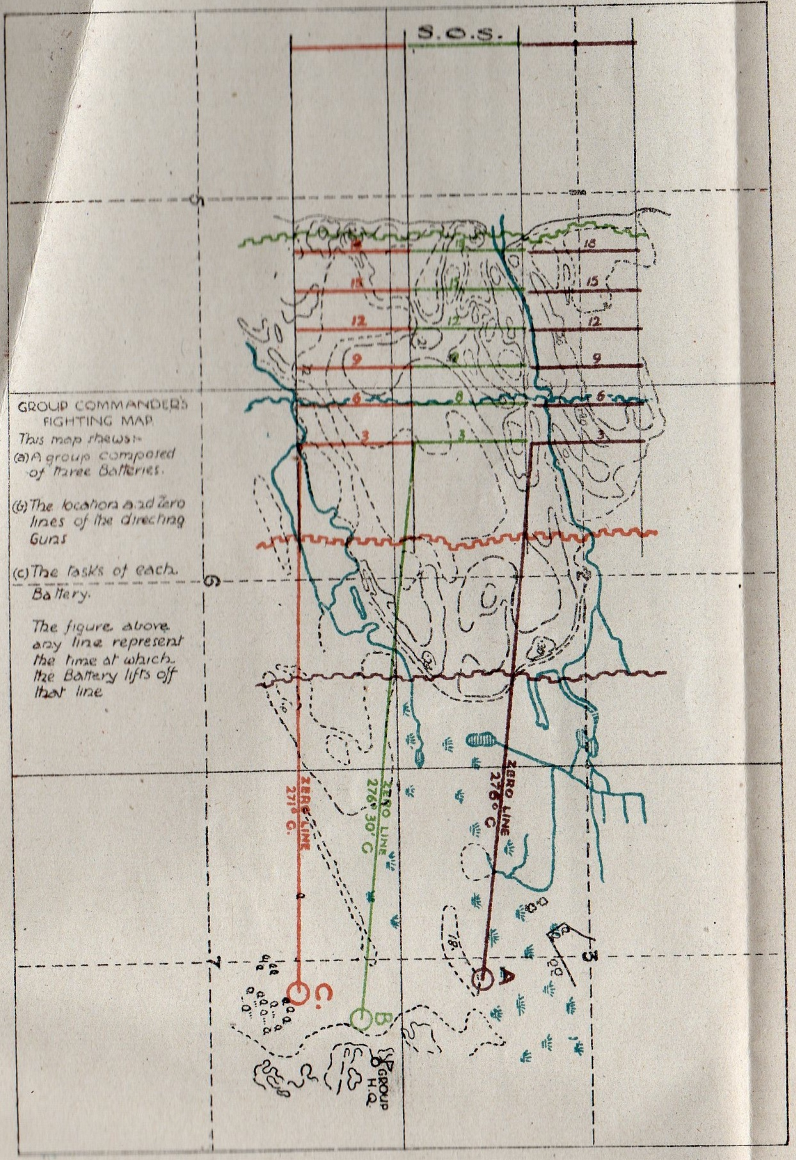
Chart of Concentration Points.

No. of Point	Angle from Zero Line	Q.E.	REMARKS
1	5° LEFT	6° 30′	Strong Point 5b 2.2.
2			
3			

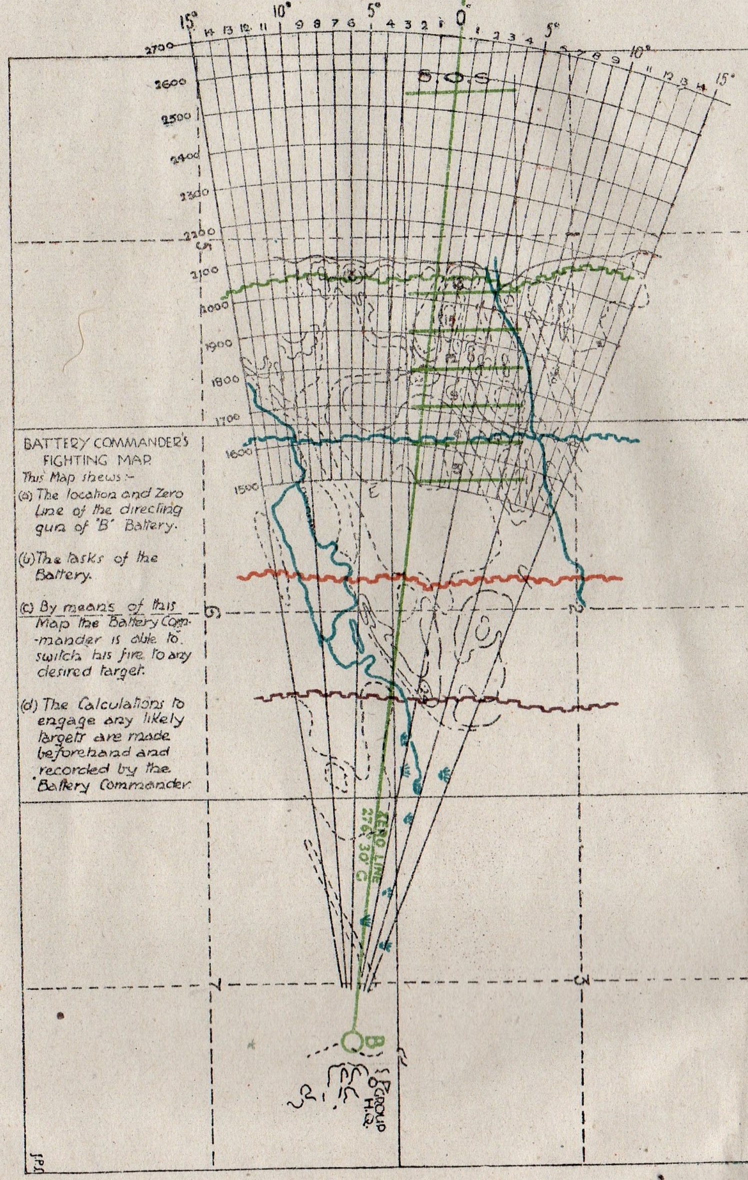
APPENDIX VII.

FIGHTING MAPS.

GROUP COMMANDER'S.



BATTERY COMMANDER'S.



To face page 122.

APPENDIX VIII.

COMPASS TOWER.

Description.

The "Compass Tower," shown in the accompanying photograph has been designed for the purpose of laying the gun quickly and accurately on any given bearing by direct use of the Compass.

Experiments showed that the iron of the tripod did not affect the readings of a compass placed directly above the socket at a height of not less than 14 inches (the gun having been removed).

The pattern of tower illustrated is constructed of wood (mahogany). It is held upright by the crosshead joint pin to which it can be clamped by means of a wing nut. On the table forming the top of the instrument, a compass can be placed and held from moving by a leaf spring; the latter projects up through a hole in the table and presses the compass case against two round-headed screws.

The crosshead joint pin makes an angle of 90° with the axis of the bore, and the compass can be adjusted rapidly by means of an adjustable sight vane on the table, so that the line of sight through the compass is at right angles to the crosshead joint pin, and therefore parallel to the axis of the bore.

The overall length of this model is 16 inches; width $2\frac{1}{4}$ inches; weight 12 ounces.

Method of use.

To adjust: Lay the gun on some distant object, and tighten the traversing clamp securely. Remove the gun from the crosshead to a distance of at least three yards.

Place the compass tower in position on the crosshead, replace the crosshead joint pin, and clamp the tower in position by means of the clamping nut.

Place the compass on the table, and align it on the object by rotating the compass. Bring the sight vane of the compass tower into alignment with the hair line of the compass, and then clamp up the sight vane.

The compass tower will now be in adjustment.

To lay the gun on any magnetic bearing: Remove the gun from the vicinity of the tripod, and loosen the traversing clamp; place the compass tower on the crosshead, and align the hair line of the compass on the slit of the compass tower sight vane.

Rotate the crosshead until the required reading is seen on looking through the compass prism (or its equivalent).

Clamp up the traversing clamp; loosen slightly the clamping nut of the compass tower, and withdraw the crosshead joint pin. Remove the compass tower from the crosshead, and replace the gun which will now be pointing in the required direction.

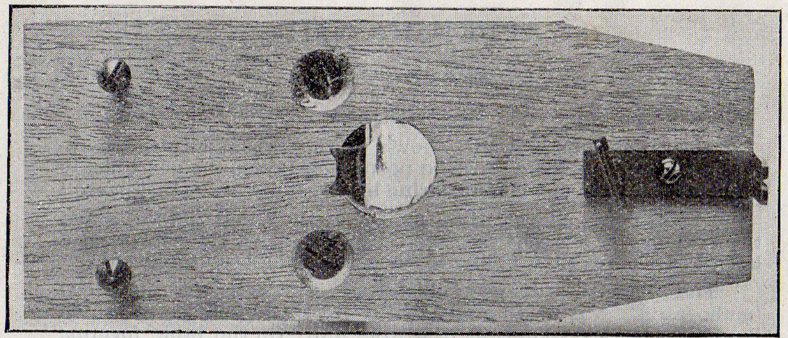


Fig. 1.—Plan of table of Compass Tower viewed from above.

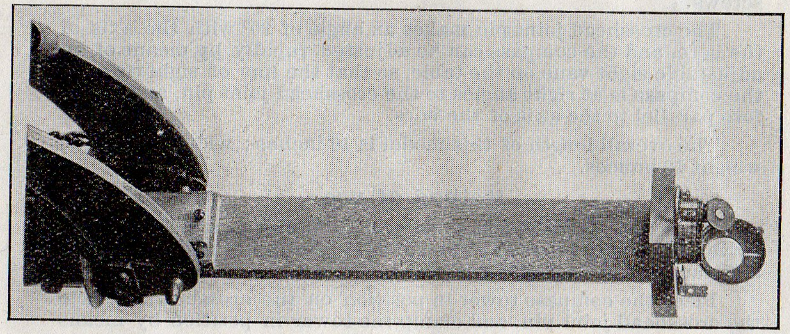


Fig. 2.—Perspective view of Compass Tower in position on the crosshead, compass in position.

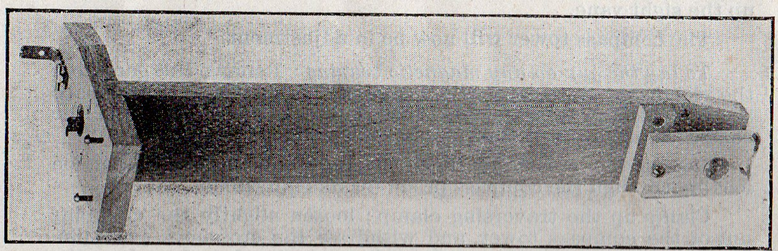
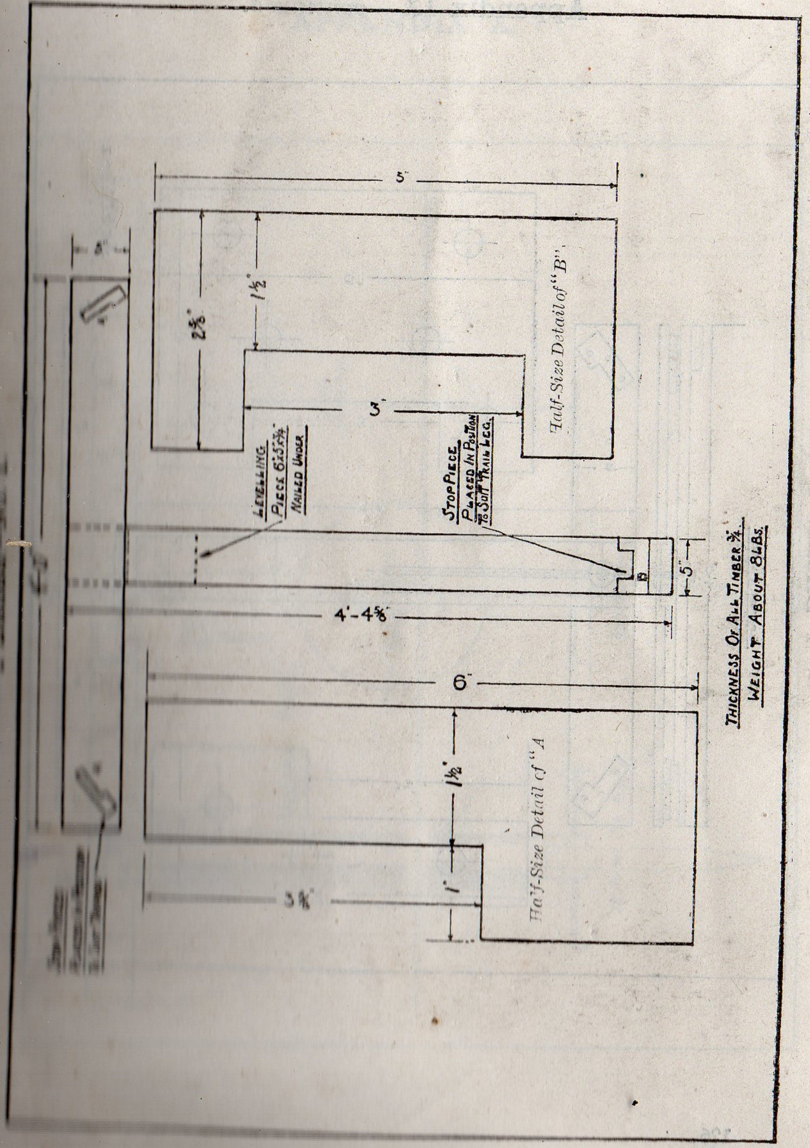
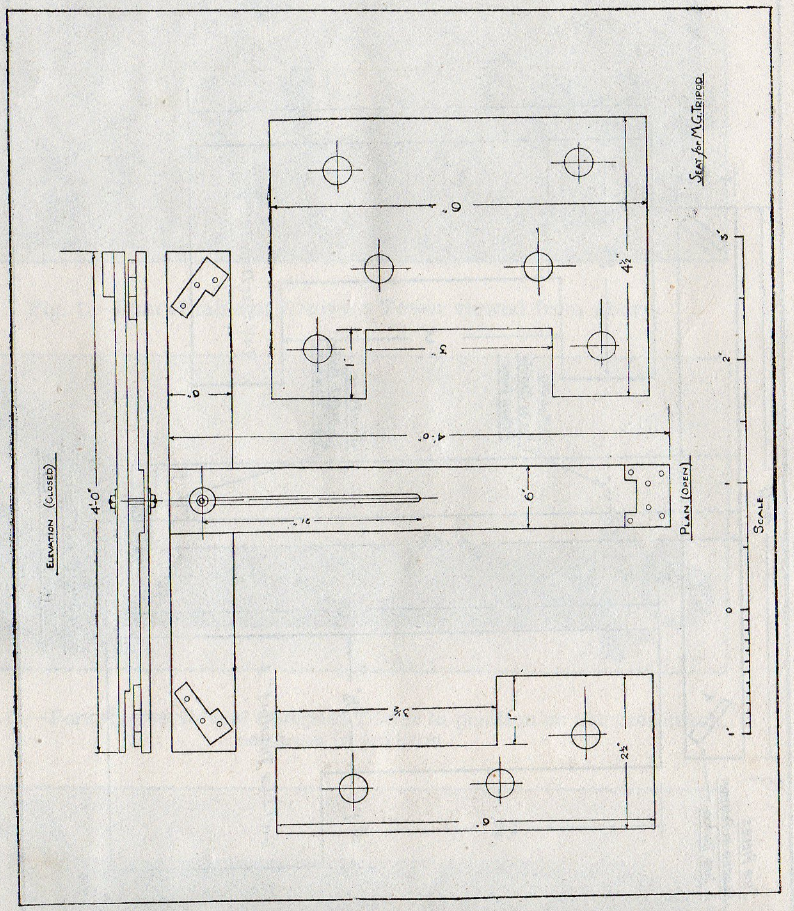


Fig. 3.—Perspective view of Compass Tower showing table, sight vane, and securing clip.

APPENDIX IX.

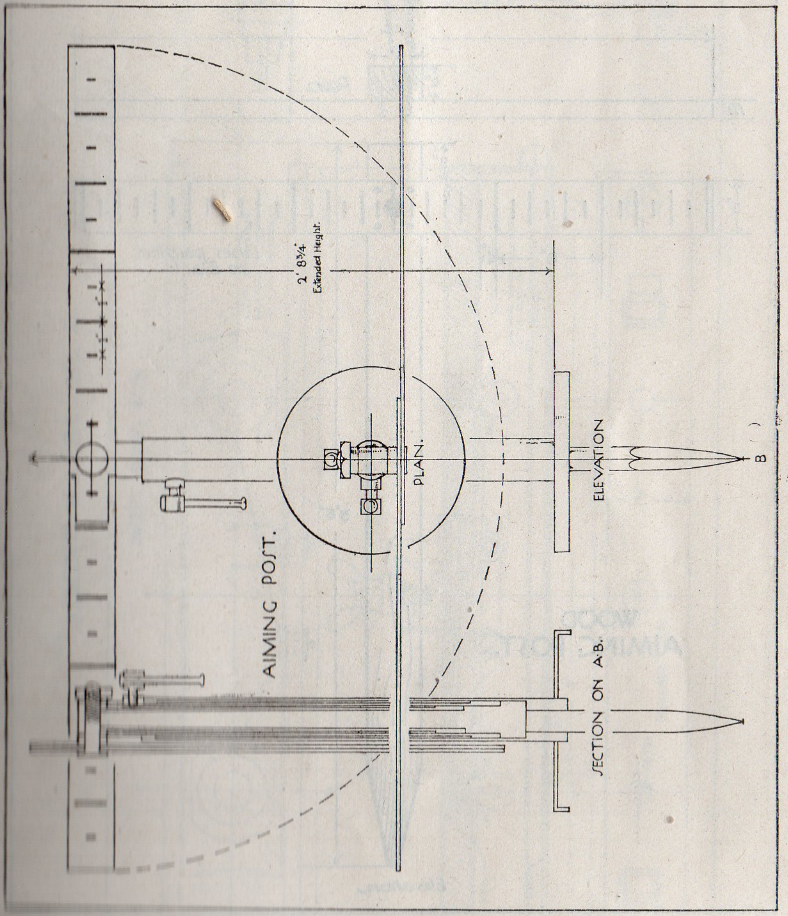


T BASES.—No. 2.



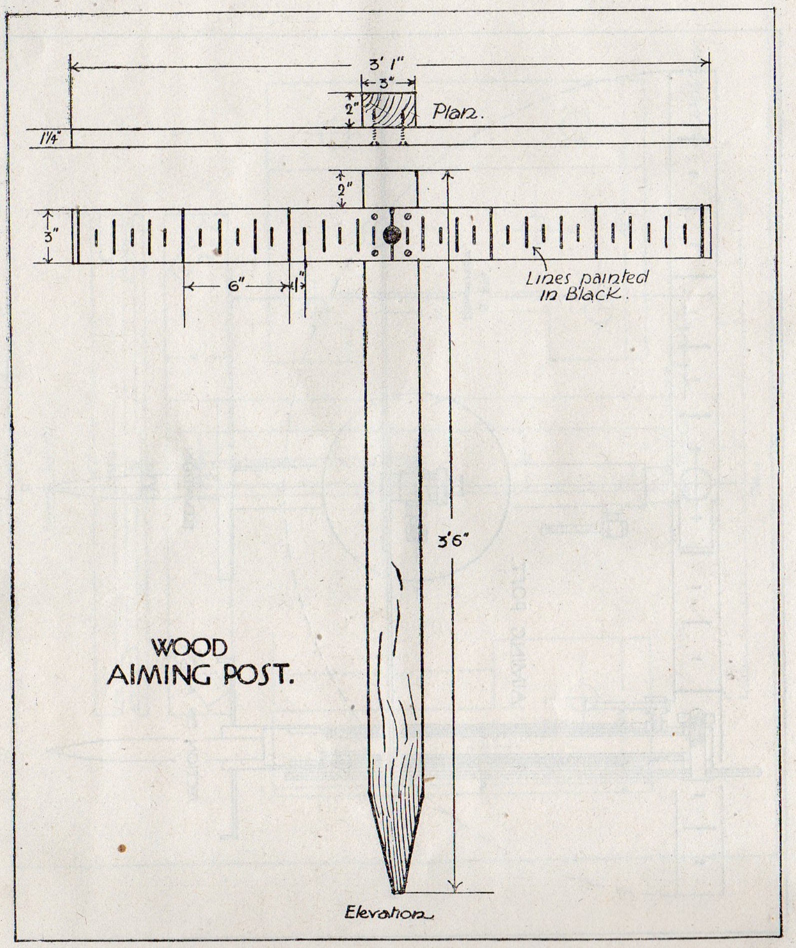
APPENDIX X.

AIMING MARKS.—No. 1.



Appendix X.—*continued.*

AIMING MARKS.—No. 1a.



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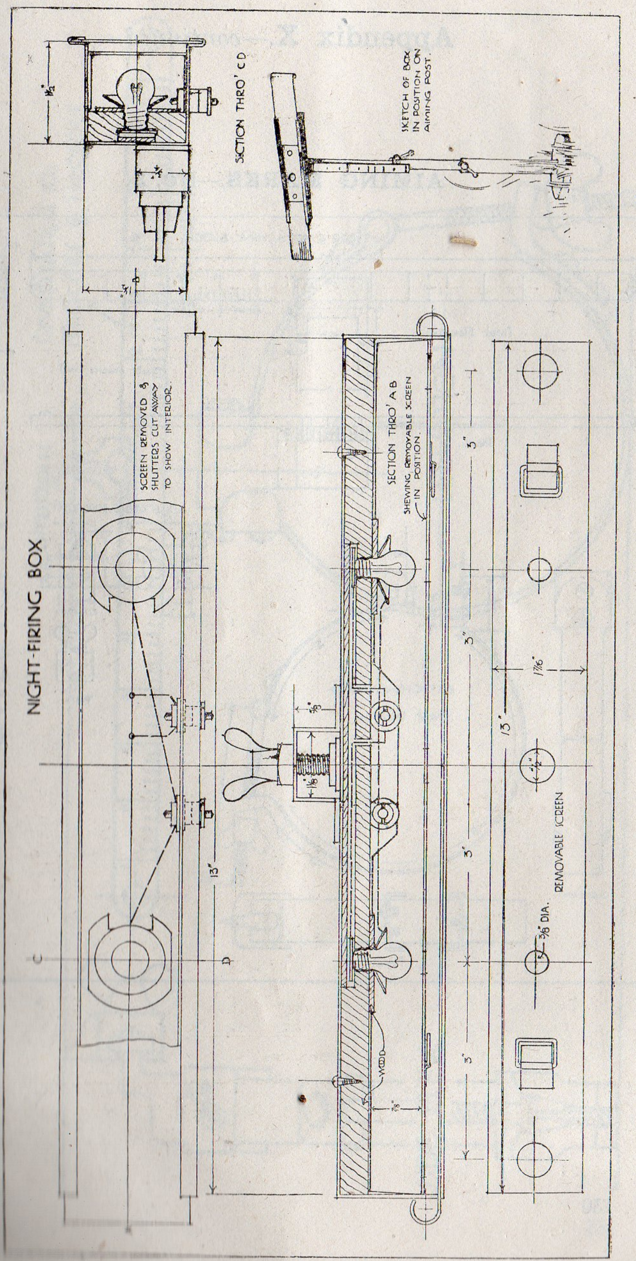

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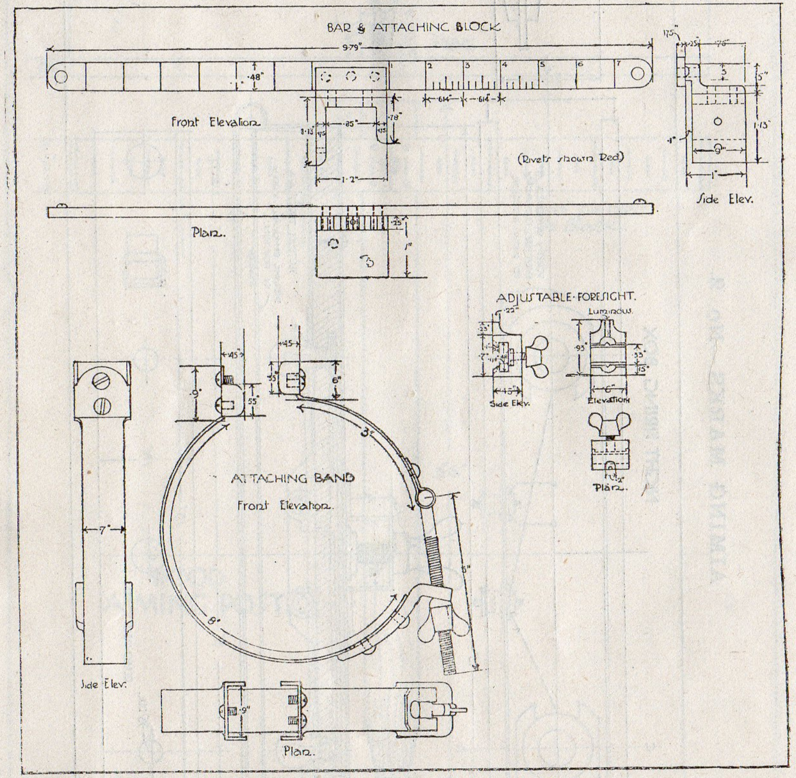

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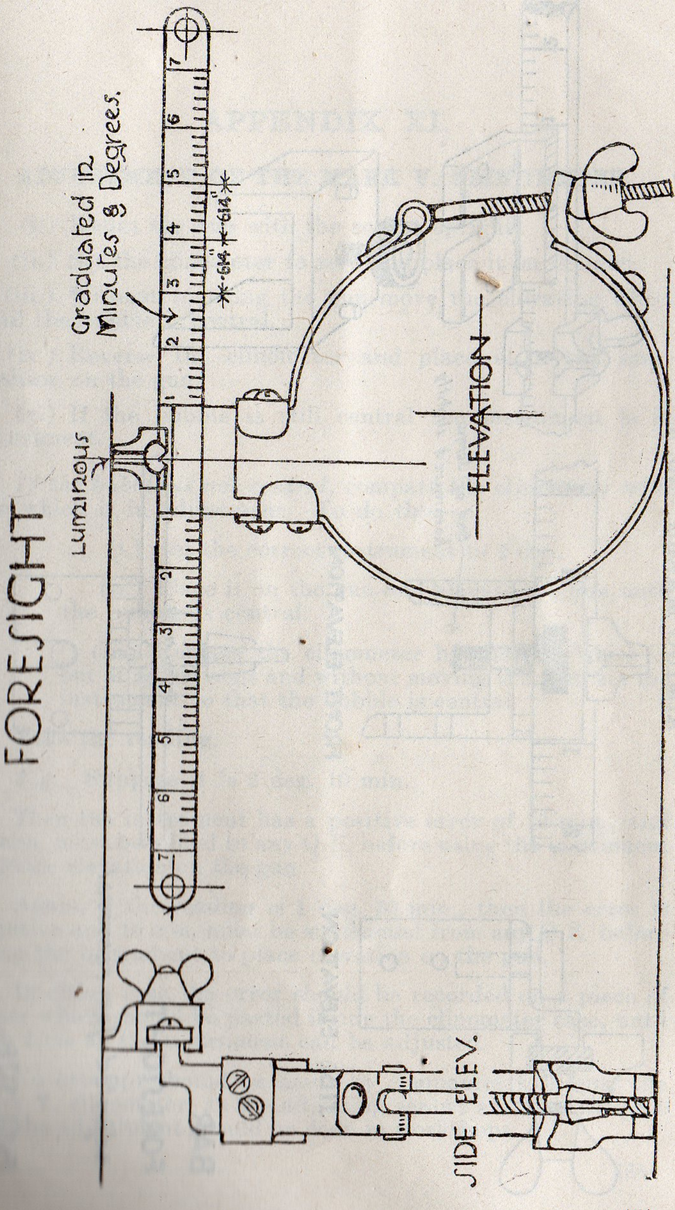

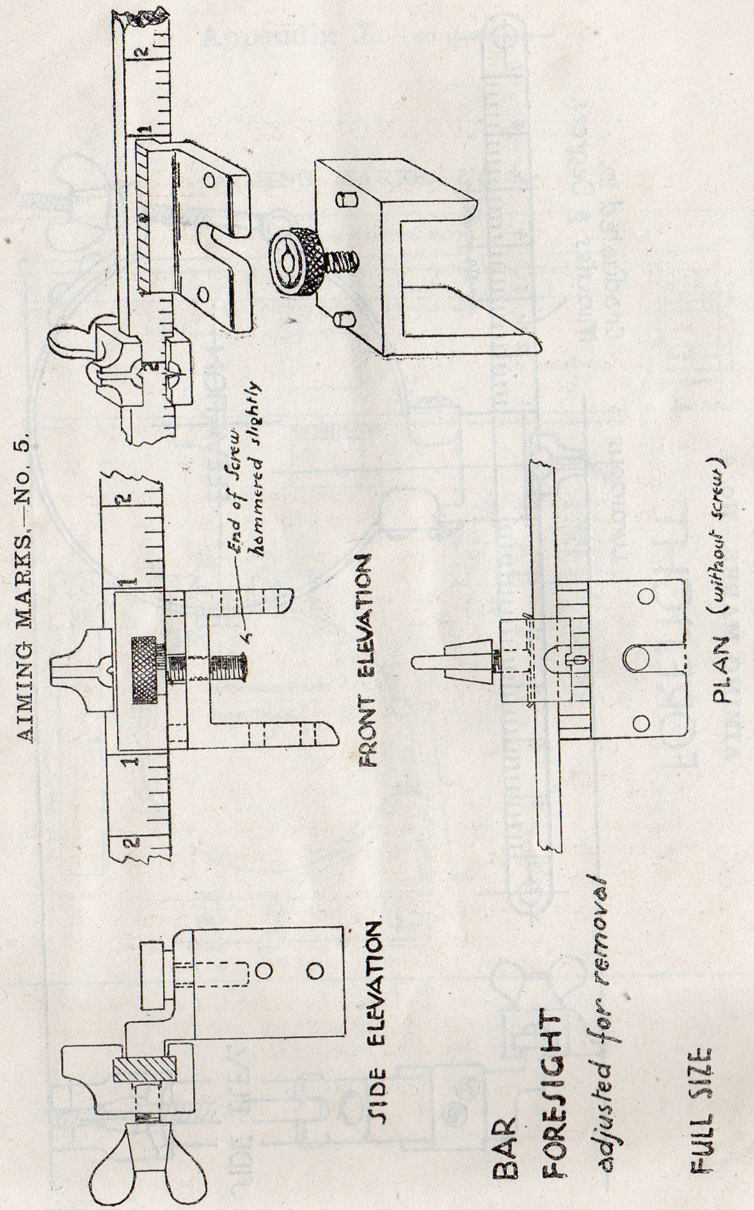

APPENDIX XI.

ADJUSTMENT OF THE MARK V. CLINOMETER.

(i.) Mount the gun with the socket upright.

(ii.) Set the clinometer to zero and place it on the gun.

(iii.) Without touching the gun move the elevating wheel until the bubble is central.

(iv.) Reverse the clinometer and place it in the same position on the gun.

(v.) If the bubble is still central the instrument is in adjustment.

If the bubble is not central, compare the clinometer with one which is in adjustment. To do this—

(i.) Set the correct instrument to 2 deg.

(ii.) Place it on the gun and elevate the gun until the bubble is central.

(iii.) Replace the clinometer by the one which is out of adjustment and without moving the gun, set the instrument so that the bubble is central.

Take the reading.

E.g. Suppose it is 2 deg. 10 min.

Then the instrument has a positive error of 10 min., and 10 min. must be added to any Q.E. before using the instrument to place elevation on the gun.

Again, if the reading is 1 deg. 50 min., then the error is negative and 10 min. must be subtracted from any Q.E. before using the instrument to place elevation on the gun.

In either case the error should be recorded on a piece of paper which should be pasted inside the clinometer case, until such time as the instrument can be adjusted.

No attempt should be made by companies to adjust the Mark V. clinometer, as the adjusting screws are very delicate and the adjustment should be done in workshops.

APPENDIX XII.

CARE OF MACHINE GUNS IN FROSTY WEATHER.

1. Not more than about 5 pints of water should be put into the barrel casing, and 20 per cent. of glycerine will prevent it from freezing quickly. In extremely hard weather, if the gun has to be exposed, experience has proved that $2\frac{1}{2}$ pints of water plus $2\frac{1}{2}$ pints of pure or residue glycerine is necessary. A drawback, however, to the large proportion of glycerine is that if fire is sustained until the mixture boils very bad fumes are given off. If the gun is used in a covered emplacement these fumes have more effect upon the team than the fumes given off by cordite.

2. Working parts should be slightly oiled with a lightly oiled rag. If firing is sustained oil must be applied to all frictional parts.

3. Guns should be wrapped in blankets, sandbags or rope, etc., and kept near braziers or in men's dug-outs or close to the body till required. If none of these courses is possible, the recoiling portions should be frequently worked, or single shots fired and the lock be changed at interals, the spare lock being kept in a clean pocket close to the body.

4. A proportion of ammunition should, if possible, be kept warm and changed at intervals.

5. If possible, some oil should be kept warm for use if firing is prolonged.

6. Should the water in the barrel casing become frozen solid, on the gun being fired the barrel will probably not recoil far enough to work the gun and will remain back. To remedy this, pull the crank handle on to the roller, then bring it back to a vertical position and force the barrel to the front, pulling the belt if necessary; let the crank handle return to the check lever and fire the gun. This should be repeated until the barrel recoils correctly.

7. If a gun is exposed in extremely hard weather, fuzee and other springs become brittle, and lose their quickness. Fuzee springs should be lightened, as the frost tends to increase their weight.